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Construction Planning and Execution Strategies for Enhancing Project Success on Electrical Construction Subcontracts

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Construction Planning and Execution Strategies for Enhancing Project Success on Electrical Construction Subcontracts

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Dedication

I dedicate this dissertation to my parents, Soo-Seob Kim and Jong-Hee Kweon. There is no doubt in my mind that without their continued support and love I could not have completed this process. Particular thanks also go to my wife, Jihyun Lee, to my brother, Dae Hee Kim, to my sister-in-law, Jeong Sook Lee, to my nephews, Do Hyun Kim and Soo Hyun Kim, to my sister, Jung Hee Kim, to my brother-in-law, Byung Taek Ha, and to my nephews, Yoo Jeong Ha and Seong Hoon Ha, all for instilling in me the desire to learn and the drive to succeed.

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Construction Planning and Execution Strategies for Enhancing Project Success on Electrical Construction Subcontracts

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Abstract

As subcontractors, electrical contractors have been facing unfavorable environments, with problems such as constrained job site areas, schedule interference, and inefficient communication with other trades. To achieve desired goals more efficiently, electrical contractors require a more systematic and effective project management strategy. The primary goal of this research is to develop continuous task strings that pair pre-construction planning (PCP) with relevant project execution (PE) tasks in order for electrical contractors to achieve significantly better performance. Incorporating several statistical analyses, the research demonstrates the effects of continuous task strings on project performance in terms of cost and schedule success. The results reveal that the levels of task string usage are significantly correlated to project success. Moreover, task strings have significant leveraged effects on project performance: project performance can be improved by stringing together related PCP and PE tasks as opposed to performing either PCP or PE task individually. The research further suggests the specific high-value task strings that significantly increase the likelihood of achieving

successful project outcomes. Ultimately, by elucidating the relationship between pre-construction planning and project execution tasks, the research can help electrical contractors accomplish significantly better performance through effective project management strategies.

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SECTION I: RESEARCH DESIGN

Chapter 1: Introduction

1.1 BACKGROUND

Because of recent scientific and technological advances, electrical construction requires more sophisticated and complex work, and as a consequence, the electrical market has become highly competitive. Typically, electrical contractors are subcontracted by the general contractor to provide their specialized skills. As subcontractors, electrical contractors have been facing unfavorable environments, with problems such as constrained construction site areas, schedule interference, and inefficient communication with other trades. Due to this adverse environment, electrical construction projects are subject to decreased productivity, inefficiency, and schedule delays (Guo 2002; Horman et al. 2006). It only takes one failed project to drive profit margins down significantly, when projects are not managed efficiently. Therefore, electrical construction currently requires a more systematic and effective project management strategy to achieve desired goals.

1.2 RESEARCH NEEDS

Despite the unfavorable environments of electrical construction projects, relatively little research on effective project management for electrical construction has been done. Two recent studies provide the underlying motivation to move forward to enhance project management effectiveness, which ultimately contributes to performance improvement. These studies include the pre-construction planning process (Menches and Hanna 2006) and the project execution process (Nasr 2009). The pre-construction planning process consists of a set of core tasks selected from the outstanding processes of successful electrical projects. Subsequently, a model project execution process was also

formalized based on the tasks that were implemented by electrical contractors. These two individual models provide fundamental electrical construction processes that can improve the chances of achieving project success.

Furthermore, Menches (2006) proposed a conceptual model of the relationship between project characteristics, pre-construction planning, project execution, and performance. The model suggested that three factors–characteristics, planning, and management–were inherently related to each other. Accordingly, project characteristics will or might influence planning and execution, which continuously influence performance by interacting mutually. Therefore, the conceptual model emphasized the combined effects of planning and execution on project performance. Figure 1.1 graphically shows the relationships among these four factors.

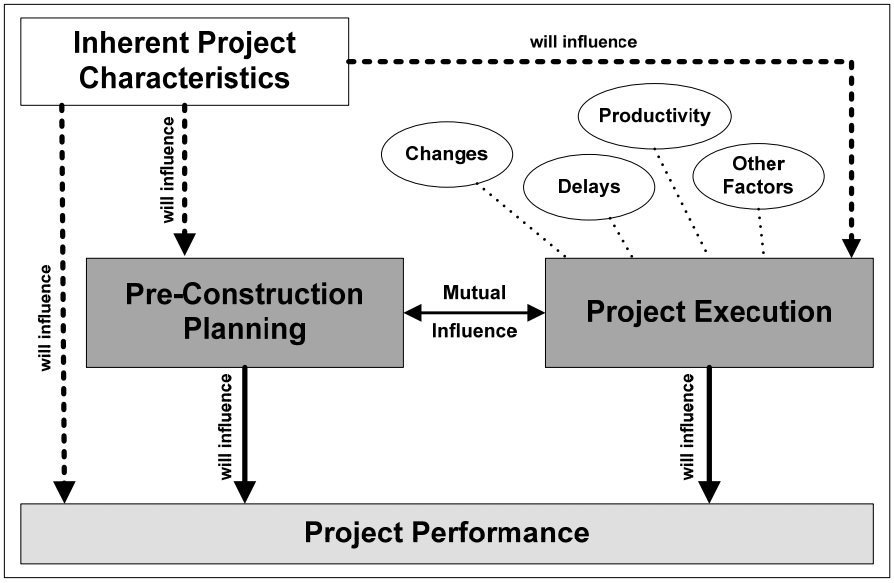

Figure 1.1: Conceptual Model of the Relationship Between Characteristics, Planning, Project Execution, and Performance (Menches 2006; Nasr 2009)

One of the main objectives of pre-construction planning is to establish systems that support effective project execution by managing problems associated with project execution (Nasr and Menches 2009). Thus, project execution (PE) tasks need to be paired with relevant pre-construction planning (PCP) tasks to be effectively performed. However, there is still a lack of evidence of the effects of those related task strings on project performance. Furthermore, little research on the relationships between pre-construction planning and project execution has been done. Therefore, there is a critical need to develop continuous task strings that link pre-construction planning to relevant project execution tasks in order to achieve significantly better project performance.

1.3 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

The primary goal of this research is to identify the important task strings between pre-construction planning and project execution that lead to significantly better performance. To meet this research goal, continuous task string models were developed by linking project planning tasks to relevant project execution tasks. The research focus is also extended to suggest effective project management strategy by providing a list of high-value task strings that significantly contribute to project performance improvement. To accomplish the research goal, the following objectives are proposed:

- Develop the relationship between PCP and PE tasks.
- Investigate the influence of task strings between pre-construction planning (PCP) and project execution (PE) on project performance.
- Understand the relative importance of the strings between PCP and PE tasks

Three sets of research questions were developed in order to achieve the research objectives. The research will ultimately answer the following questions:

- What are the continuous task strings between pre-construction planning and project execution?
  (a) Which PCP tasks need to be performed for successful implementation of PE tasks?
  (b) How important is it to complete the PCP tasks in order to effectively implement the PE tasks?

- What are the effects of task strings on project success?
  (a) How do levels of task string usage impact?
  (b) Does implementation of task strings leverage impact?

- Which specific task strings have potentially greater impact on performance?
  (a) Which specific task strings may contribute to project success?
  (b) How much value is added for the specific task string as opposed to implementing either PCP or PE task individually?

1.4 RESEARCH SCOPE LIMITATIONS

The scope of work includes: (1) development of task string models that link pre-construction planning tasks to project execution tasks; (2) investigation of the influence of the continuous task strings on project performance; and (3) suggestion of the high-value task strings proven to leverage project performance for effective project management. In addition, the research effort is limited to U.S. electrical construction

contractors. The research scope is further limited to post-bid tasks including pre-construction planning and project execution. A small number of electrical projects (N=50) is also a potential limitation.

1.5 DISSERTATION STRUCTURE

This dissertation is organized into twelve chapters and includes a set of appendices containing supporting information and results of data collection and analysis. Chapter Two provides a review of previous studies on task models in electrical construction. Chapter Three presents the research methodology that outlines the processes of the study and provides a description of each step of the study.

The next three chapters focus on the development of task strings between pre-construction planning and project execution. Chapter Four describes data-based pre-screening to eliminate inappropriate pre-construction planning and project execution tasks for task string development. Chapter Five develops the continuous task string models that link pre-construction planning tasks to relevant project execution tasks. Chapter Six validates the task string models developed in the previous chapter through second-round expert-opinion based surveys.

The analyses of the influence of task strings are summarized in the next five chapters. Chapter Seven describes the research hypotheses and procedures to investigate the influence of the task strings on project performance. Chapter Eight calculates the task string implementation score that quantifies the effort of task string implementation and identifies the effects of levels of task string usage on project success. Chapter Nine investigates the leveraged effects of the task strings on project performance as opposed to individual PCP or PE tasks. Chapter Ten suggests a list of the ranked task strings that

potentially contribute to project performance. Chapter Eleven validates the effects of task string implementation on project success. The research is concluded in Chapter Eleven with a summary of research findings and recommendations.

Chapter 2: Literature Review

2.1 INTRODUCTION

A literature review was conducted to identify what has been done and what is missing in current electrical construction studies. As subcontractors, electrical contractors have been facing adverse conditions, such as constrained construction site areas, schedule interference, and inefficient communication with other trades. Despite the unfavorable environments of electrical construction, relatively little research on project management for electrical construction has been done. This review highlights two of the most significant recent studies that delineate the critical electrical project management tasks, including (1) electrical pre-construction planning tasks (Menches and Hanna 2006) and (2) electrical project execution tasks (Nasr 2009). These studies laid the foundation of electrical project management knowledge on which this research is based.

2.2 PRE-CONSTRUCTION PLANNING

One of the main objectives of pre-construction planning is to make a plan to ensure successful implementation of project execution. The planning process generally occurs between contract award and project execution. According to Laufer et al. (1993), pre-construction planning can last as long as three months after the bid-award. During the planning phase, contractors address issues that could occur during the construction execution phase. Pre-construction planning may include a group of tasks and their related methods and techniques that provide the basis for the work that is to be completed. The various definitions of pre-construction planning are summarized below:

> Planning is a process of deciding what to do and how to do it before action is required. Planning includes the integration of a set of interdependent decisions. The plan is the formulation of the results of this process. (Laufer et al. 1993; Menches 2006)

> Preplanning in essence involves setting down procedures in detail about who, what, why, how, when, and where; and it is done well in advance of the time when particular tasks are to be undertaken. (Menches 2006; Oglesby et al. 1989)

> Pre-construction planning is the strategy phase of a construction project. It must begin before the first worker arrives, before the first piece of material is ordered, and before everything begins.(PHCC 2003)

> Pre-construction planning is the planning that is performed to prepare a construction project for execution. Pre-construction planning is also referred to as execution planning, pre-job planning, and more generically as pre-planning, which is a term applied in many fields to refer to that stage of planning that occurs before an event happens.(ELECTRI International 2009)

> A comprehensive set of procedures that is completed by the contractor in the period between contract award and construction execution. (Hanna and Skiffington 2010)

The effects of pre-construction planning have also been investigated by several researchers. Menches (2006) demonstrated that the implementation of the pre-construction planning tasks significantly improves the likelihood of project success in electrical construction projects. More recently, Hanna and Skiffington (2010) also highlighted the effect of pre-construction planning on sheet metal projects. They found that well-planned projects achieved an average profit margin of 23%, while poorly planned projects made an average profit margin of -3%. Moreover, the Plumbing-Heating-Cooling Contractors National Association (PHCC) emphasized the benefits of pre-construction planning, particularly its effectiveness at improving productivity, decreasing safety-related accidents, and increasing profit (Hanna and Skiffington 2010; PHCC 2003).

2.3 ELECTRICAL PRE-CONSTRUCTION PLANNING (PCP) TASKS

In a previous study, Menches and Hanna (2006) developed a model pre-construction planning process for electrical construction. The initial planning process included 123 potential planning tasks that electrical contractors performed. To refine the initial planning process, two sample comparisons were conducted using cross tabulation and correlation analyses. These analyses compared the difference in implementation of PCP tasks between successful and less-than-successful projects. The selection criteria for significant PCP tasks are summarized below (Menches 2006):

1. The task was performed frequently by both successful and less-than-successful projects (frequency of task performance was greater than 50 percent), or
2. Significantly more successful projects performed the task than less-than-successful projects (p-value ≤ 0.05), or
3. There was a strong correlation between task performance and outcome (p-value ≤ 0.05), where performance of the task resulted in a positive outcome.

As a result of the analysis, 46 critical tasks were selected in the pre-construction planning stage. These tasks were further grouped into ten categories based on the association of tasks. These categories include team selection and turnover, scope and contract review, administrative setup, buyout process, material handling plan, budget preparation, layout and sequencing plan, schedule development, tracking and control, and construction execution kickoff meeting. Descriptions of these categories are summarized below:

1. *Team Selection and Turnover:*

   Select project management staff and field supervision, and transfer the bid planning knowledge over to the project management staff.

2. *Scope and Contract Review:*

   Review the contract documents to understand the nature of the work, including plans, specifications, contracts, and technical reports.

3. *Administrative Setup:*

   Set up project files, enter the project in a computer database, and prepare the system for efficient operations, including a change management system and request for information (RFI) system.

4. *Buyout Process:*

   Solicit suppliers for material pricing, negotiate purchase orders, order the materials, and process the submittals.

5. *Material Handling Plan:*

   Receive and store major materials and equipment on the jobsites or at a storage location.

6. *Budget Preparation:*

   Develop a cost code scheme and break down materials, labor, and overhead into discrete categories that can be used for billing during execution.

7. *Layout and Sequencing Plan:*

   Develop a sequence of work, lay out that sequence in a series of drawings for field execution, and develop installation instructions for crew members.

8. *Schedule Development:*

   Convert a sequencing plan into a set of discrete tasks that can be mapped onto a timeline.

9. *Tracking and Control:*

   Develop a labor and materials tracking report and create essential reports in a computer database.

10. *Construction Execution Kickoff Meeting:*

    Call together all team members in order to review communication processes, administrative procedures, reporting requirements, and schedules immediately prior to executing the work

The study also analyzed the relationship between pre-construction planning and project performance. Six performance measurement variables were identified: (1) actual percent profit; (2) percent schedule overrun; (3) amount of time given; (4) communication between team members; (5) budget achievement; and (6) change in work hours. To analyze the influence of pre-construction planning tasks, these six performance variables were combined and transformed into a probability of successful performance. The analysis results revealed that those projects that performed critical planning tasks were more likely to achieve successful outcomes. Table 2.1 summarizes the 46 pre-construction planning tasks.

Cat	#	Pre-Construction Planning Task
Team Selection & Turnover	1	Finalize selection of project manager, field supervisor, and other key team members
	2	Hold turnover meeting between estimator and project manager
	3	Hold separate turnover meeting between project manager and field supervisor
	4	Hold pre-job (planning) kickoff meeting with internal team members to assign responsibilities
Scope & Contract Review	5	Review contract for unfavorable or high risk clauses
	6	Review plans, specifications, and schedule (Project manager)
	7	Review plans, specifications, and schedule (Field supervisor)
	8	Create a list of issues that need to be resolved and begin the request for information (RFI) process
	9	Conduct site visit
	10	Compare estimated (bid) work activities & materials to planned performance
	11	Identify value engineering and prefabrication opportunities and how to simplify the work
	12	Prepare construction takeoff
Administrative Setup	13	Set up project files and create contact list
	14	Set up computerized tracking and control system (forms, database, schedule, tracking)
	15	Initiate a change management system
	16	Initiate a request for information (RFI) tracking and processing system
	17	Initiate a submittal tracking and processing system
	18	Develop a "Labor Requirements/Expectations" letter
Buyout Process	19	Review subcontractor/supplier/vendor prices and qualifications
	20	Negotiate pricing & contract conditions and select subcontractors/suppliers/vendors
	21	Develop and issue purchase orders and contracts for materials and equipment
	22	Order long-lead-time materials and equipment
	23	Request submittals, cut sheets, and shop drawings
	24	Develop and process log and book of submittals, cut sheets, and shop drawings
Material Handling Plan	25	Develop material delivery and handling plan
	26	Develop material storage and staging plan
Budget Preparation	27	Develop, review, or expand cost code scheme
	28	Develop budget by breaking down labor, material, overhead, and profit costs
	29	Develop schedule of values
Layout & Sequencing Plan	30	Develop installation sequence and layout drawings
	31	Develop field instructions, including panel, pull, or conduit schedules
	32	Develop prefabrication drawings for field use (when applicable)

Table 2.1: Pre-Construction Planning Tasks.

Cat	#	Pre-Construction Planning Task
Schedule Development	33	Review customer's schedule and timeline
	34	Identify work that impacts electrical activities
	35	Review the work sequence and long-lead-time material/equipment delivery dates
	36	Coordinate electrical schedule with the customer's schedule
	37	Create a bar chart schedule
Tracking & Control	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project
	39	Develop labor and materials tracking report
Construction Execution Kickoff Meeting	40	Review meeting schedule
	41	Review request for information (RFI) process
	42	Review change order process and field change management process
	43	Review submittal processing procedure
	44	Review billing and invoicing procedures
	45	Review project and field reporting and tracking procedures
	46	Review electrical and customer schedules

Table 2.1: Pre-Construction Planning Tasks (Continued).

2.4 PROJECT EXECUTION PROCESS

Most contractors devote their efforts to achieving successful outcomes of projects. One of the efforts on which contractors spend most of their time is project execution. The execution process is generally implemented based on a project plan that should be developed in the pre-construction planning phase. As a result, contractors put their effort into managing issues that occur during the project execution phase to achieve project objectives. During the project execution phase, all aspects of the project are managed to ensure that the work of the project is performed correctly. Accordingly, a group of related methods and techniques were implemented based on the project plan. The fundamental project execution areas may include cost management, schedule management, scope

management, human resource management, procurement management, safety management, risk management, and communication management (Kerzner 2006).

The importance of project execution has long been acknowledged and as a result, numerous studies on it have been done. The Project Management Institute (PMI 2004) defined project execution as integration of people and resources to effectively implement the project plan for the successful outcome of the project. PMI's study also emphasized the controlling process, which includes regularly monitoring the progress of the project and taking corrective action to meet the project objectives.

The effect of project execution on project performance was also demonstrated by many researchers (CII. 1999; Jaselskis and Ashley 1991; Russell et al. 1997). Kerzner (2006) pointed out that the failure of a project was mainly caused by an ineffective project execution process. The specific reasons for the failure include ineffective scheduling, ineffective estimating, ineffective cost control, project objectives being "moving targets," poor morale, poor motivation, poor human relations, poor productivity, no employee commitment, no functional commitment, delays in problems solving, too many unresolved policy issues, and conflicting priorities between executives, line manager, and project manager.

2.5 ELECTRICAL PROJECT EXECUTION (PE) TASKS

In a recent study, Nasr (2009) developed a model electrical project execution process by incorporating current tasks that were performed on successful projects. He conducted comprehensive site visits with 25 electrical companies across the United States: Each company provided data on two projects, including a successful project and a less-than-successful project, and as a result, data on a total of 50 projects were collected.

To analyze the data, the execution tasks of each project were encoded using a binary scale (Yes=1 or No=0) based on whether or not the companies performed the task. The results of the initial data analysis produced 370 project execution tasks which were further grouped into 93 tasks by combining similar tasks. Subsequently, the 93 project execution tasks have been condensed into 85 tasks for the model project execution process. Like the pre-construction planning tasks, the project execution tasks were subject to the same selection criteria. The three main criteria are summarized below (Nasr 2009):

1. The task was performed frequently by both successful and less-than-successful projects (frequency of performance was greater than 50 percent), or
2. Significantly more successful projects performed the task than less-than-successful projects (p-value ≤ 0.05), or
3. There was a strong correlation between task performance and outcome (p-value ≤ 0.05), where performance of the task resulted in a positive outcome.

The model electrical project execution process consists of 85 tasks, including 80 significant tasks and 5 recommended tasks. These 85 tasks were classified into 14 task categories. These project execution categories include mobilization, document management, material management, tool management, subcontractor management, safety, communication, coordination, scope and change control, scheduling, cost control and billing, quality management, labor management, and project closeout. The specific PE tasks are listed below in Table 2.2.

Cat	#	Project Execution Tasks
Mobilization	1	Setup office trailer in a timely manner and in a convenient location
	2	Setup storage trailer and lay down area
	3	Setup communication system
	4	Secure access to site
	5	Bring in needed labor, tools, and material to get started
	6	Walk through the job site
	7	Make sure the foreman has everything he or she needs to get started
Document Management	8	Make use of a project file
	9	Use a documentation control system
	10	Use an RFI tracking and processing system
	11	Use a change order tracking and processing system
	12	Keep all schedule documentation, including delays
	13	Update as-built drawings
	14	Use a submittal tracking and processing system
	15	Use internal prefabrication drawings
	16	Keep records of meeting minutes
Material Management	17	Review bid documents for materials and vendors and any vendor responsibilities
	18	Develop and issue purchase orders for materials
	19	Establish delivery dates
	20	Request submittals, cut sheets, and shop drawings from vendors
	21	Document purchase orders
	22	Ensure good material handling on site
	23	Communicate all material information to field
	24	Check material packaging, labels, and status on site
	25	Lock in the needed prices
	26	Schedule material delivery using staged releases to the site depending on phases
	27	Make sure the invoice matches the material costs
Tool Mgmt.	28	Review contract drawing, specifications, and the bid for any special needs
	29	Schedule deliveries and pickups
	30	Track tool usage

Table 2.2: Project Execution Tasks.

Cat	#	Project Execution Tasks
Subcontractors Mgmt.	31	Review the scope and determine the subcontractors' scope of work
	32	Establish subcontracts
	33	Determine the subcontractors' schedules
	34	Request submittals and shop drawings
	35	Inform the field about the subcontractors and the people to contact
	36	Schedule on-site visit and walk through the job site with the subcontractors
	37	Make sure the subcontractors are licensed and are capable of doing the job
Safety Mgmt.	38	Ensure on-site general safety
	39	Identify safety issues with the existing job and specific job activities
	40	Plan for any additional needs for safety equipment
	41	Ensure that safety log is updated and all incidents are documented
	42	Perform job walks to ensure that the safety rules are being followed
Communication	43	Receive support from the company CEO/VP
	44	Communicate constantly with the foreman, especially when problems occur
	45	Communicate constantly with the vendors and subcontractors
	46	Communicate constantly with the General Contractor and Owner
Coordi-nation	47	Attend job site meetings and coordinate with other trades
	48	Visit the site regularly
Scope & Change Control	49	Review and understand the scope
	50	Identify problems with the drawings and specifications
	51	Submit change order requests and cost proposals
	52	Schedule meetings to discuss change issues
	53	Document change orders and incorporate them into the budget
	54	Track change orders
	55	Purchase materials or hire subcontractors and inform the field
	56	Suggest alternate processes or materials that enhance value engineering on the job site
Scheduling	57	Review the schedule and identify milestone dates
	58	Identify work that impacts electrical activity
	59	Give input about the schedule to the General Contractor
	60	Review the schedule with the field
	61	Update the schedule regularly
	62	Review or establish look-ahead scheduling process

Table 2.2: Project Execution Tasks (continued).

Cat	#	Project Execution Tasks
Cost Control & Billing	63	Use cost codes (Cost breakdown)
	64	Track labor costs
	65	Track material and subcontractor costs
	66	Include issued change orders
	67	Use the project percentage complete data
	68	Compare the project costs to the budget
	69	Use the schedule of values
	70	Bill your costs on time
	71	Use a pre-bill process
Quality Mgmt.	72	Make sure that the field is aware of the quality needed
	73	Check the quality of installation through site visits
	74	Perform test results/commissioning
	75	Use a pre-punch list
Labor Mgmt.	76	Effectively use prefabrication
	77	Maintain the correct crew mix and manpower level
	78	Ensure labor hours are turned in
Project Closeout	79	Ensure that all punch list items are signed off on
	80	Review specifications for project closeout
	81	Use a project closeout checklist
	82	Ensure that all change orders and purchase orders are closed
	83	Receive final payment and retainage
	84	Turn all project closeout documents over to the General Contractor
	85	Demobilize

Table 2.2: Project Execution Tasks (continued)

2.6 WORKFACE PLANNING (WFP)

The importance of efficient implementation of planed work has been widely recognized by the construction industry to improve project performance. Poor project management frequently impedes this construction process by increasing waste and

decreasing productivity. In particular, a large amount of productivity losses are caused by rework that is mainly due to both poor planning and poor control of construction execution (CII. 2011). To overcome the challenges of traditional project management, the concept of lean construction was adopted in the construction industry. The main focus of lean construction is waste reduction (Ballard and Howell 2003; Eriksson 2010; Green 1999; Jorgensen and Emmitt 2008; Mao and Zhang 2008). Lean construction is defined as a "way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" (Koskela et al. 2002). Lean construction primarily aims to enhance project performance by minimizing waste and maximizing value in the construction industry.

Much research effort has been made to improve productivity and efficiency in construction projects with the adoption of lean principles. Most studies have focused on the construction process, including workflow reliability and a stable process environment. To improve the reliability of planning, the Last Planner System (LPS) was introduced. The LPS aims to ensure that all resources are in place before the construction execution starts for efficient planning and control (Ballard et al. 2003; Ballard and Howell 1998; Jorgensen and Emmitt 2008). Some studies have extended to this concept to the design and delivery process including project delivery systems. The Lean Project Delivery System (LPDS) focuses on streamlining workflow by balancing inventory. This system ultimately eliminates waste and improves project quality (Ballard 2000; Ballard and Zabelle 2000).

Recently, the Construction Owners Association of Alberta (COAA) emphasized the importance of workface planning (WFP) for productivity improvement. Workface planning is defined as "the process of organizing and delivering all elements necessary, before work starts, to enable craft persons to perform quality work in a safe, effective and

efficient manner" (COAA 2006). WFP supports the construction workforce by providing detailed plans to help them efficiently execute the work. WFP encompasses Field Installation Work Packages (FIWP) that contains a list of constraints such as information, material, equipment and other resources. Work packing provides execution planning that helps foremen to perform work in an efficient manner by ensuring that all things for execution are in place. Therefore, implementation of work packaging is effective at improving productivity and performance by minimizing waste of resources and effort (CII. 2011).

These current practices of execution planning have attempted to improve productivity and project performance by minimizing waste. However, these practices may ignore the detailed level of the task interrelationships between planning and execution. In construction projects, individual tasks are inherently related to each other across different phases, including execution planning and construction execution. Nevertheless, those tasks are performed individually in the fragmented process between planning and execution without a consideration of the relationship. Thus, the understanding of these interrelationships may reinforce work packaging by allowing craft persons to effectively perform individual tasks with a consideration of the context. Moreover, awareness of these task level relationships between planning and execution may enable them to efficiently use of their efforts and to improve productivity by eliminating unnecessary tasks.

Chapter 3: Research Methodology

3.1 Overview of Research Methodology

To achieve the research goals, the research methodology was divided into three distinct stages: (1) research design, (2) model formulation, and (3) model analysis. In the initial stage, the research scope and research questions were defined by conducting an in depth review of previous studies regarding electrical project tasks. To bridge the current research gap, this study developed task string models that link pre-construction planning tasks to relevant project execution tasks. Prior to model development, a pre-screening process was used to eliminate inappropriate PCP and PE tasks based on 50 electrical projects that were recently completed. As a result, 11 PCP and 47 PE tasks were selected for task string models. With the selected tasks, the author hypothetically developed the preliminary task string models between PCP and PE. These task string models were further validated by an expert-opinion based survey that consists of two phases: (1) confirmation of discontinuous task strings, and (2) evaluation of continuous task strings. In the final phase, the continuous task string models were analyzed to investigate the effects on project performance. Based on the effects on performance, the high-value task strings that have greater effects were identified. The effects of task strings were partially validated with a statistical data analysis. The research was finally concluded with a summary of research findings and recommendations. Figure 3.1 shows the research framework to illustrate the research processes.

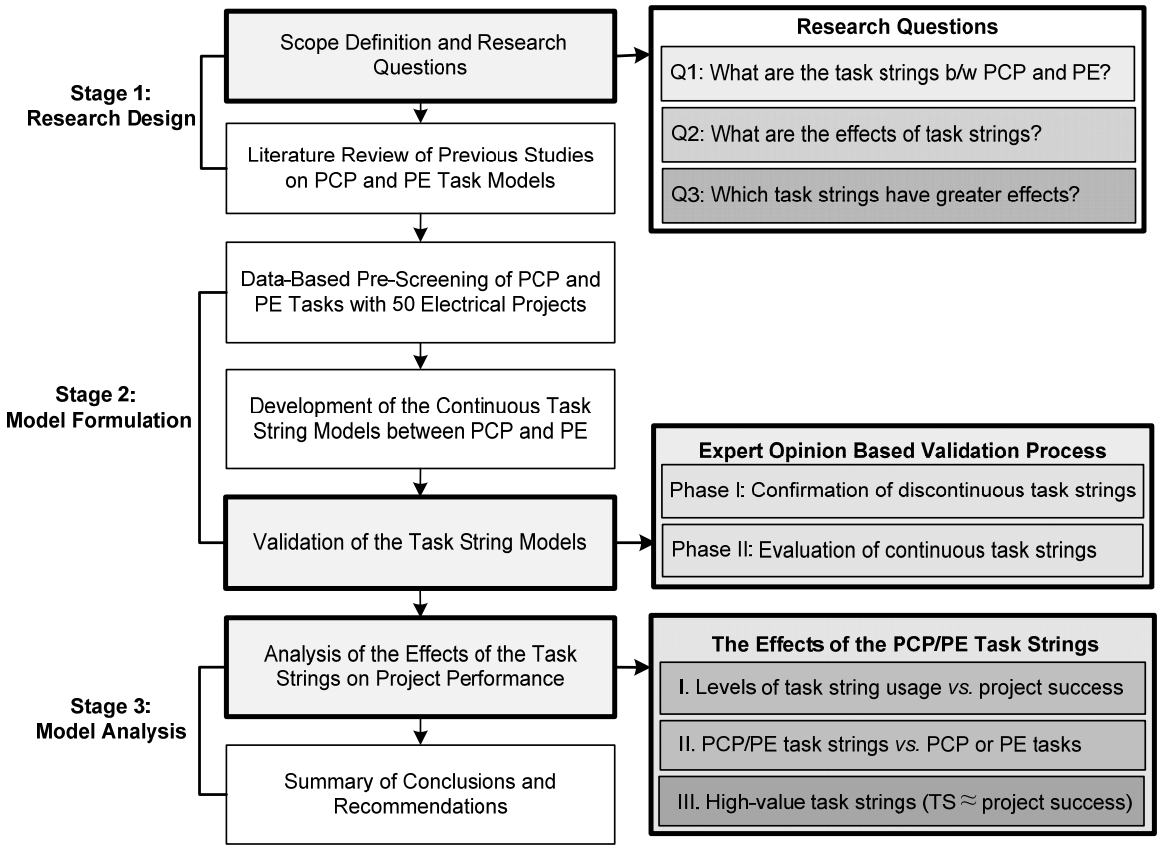

Figure 3.1: Overview of the Research Framework

3.2 TASK STRING MODEL FORMULATION

3.2.1 Overview of the Model Formulation

During the model formulation stage, continuous task string models were developed. To formulate the task string models, three sub-studies were conducted: (1) data-based pre-screening; (2) task string model development; and (3) task string model validation. Prior to the model development, a great number of inappropriate pre-construction planning tasks and project execution tasks were eliminated. Then, the author hypothetically linked PCP tasks to relevant PE tasks to identify the continuous task

strings between PCP and PE. Subsequently, the task string models were validated through an expert-opinion based survey. These validated task string models were further used to analyze the effect on project performance in the final stage.

3.2.2 Data-Based Pre-Screening

In previous studies, Menches (2006) developed a PCP task model, while Nasr (2009) developed a PE task model. Taking into account the number of each model tasks, a total of 3,910 possible task combinations between PCP and PE were created with 46 PCP tasks and 85 PE tasks. This excessively large number of task combinations, however, would cost enormous time and effort to analyze. Therefore, a data-based pre-screening was conducted to achieve robust and reliable results by eliminating inappropriate tasks. To screen out those inappropriate tasks, 50 electrical projects that were recently completed throughout the U.S. were used. These project data include specific information on project management including task implementation of each phase, and project outcomes. Therefore, an investigation of these data provides a relevant rationale to screen out inappropriate tasks. As a result of the process, a great number of inappropriate task combinations were eliminated and the mid-level of task combinations was considered for task string models.

Data Collection

In the previous study, Nasr (2009) collected 50 electrical construction projects. Twenty five electrical contractors were randomly selected from the list of 2,000 electrical members of the National Electrical Contractors Association (NECA) across the United States. The data collection process integrated face-to-face interviews and survey questionnaires. During the several site visits, relevant data were collected, including

information on pre-construction planning, project execution, and project performance. Each respondent provided two projects that were recently completed: a successful project and a less-than-successful project. After completing two questionnaires, the participants were asked to attend a four-hour interview with respect to pre-construction planning, project execution, and project performance. As a result, 50 sets of electrical project data were collected throughout the United States. These data were used for this pre-screening process as well as for further analysis in the task string study.

Data Pattern Analysis

The dataset from 50 electrical projects included task implementation of PCP and PE tasks, and other important information on project performance. To analyze those tasks, the likelihood of each task to achieve a successful outcome was calculated. By investigating task implementation and its corresponding success rate, a simple effect of task implementation on project performance was identified. This data pattern analysis provided a relevant rationale to screen out inappropriate PCP and PE tasks. For example, the tasks with high implementation may have a strong independent effect on project performance; on the other hand, the tasks with low implementation may not provide enough information on the effect of task strings. Therefore, these tasks were all excluded and only moderately implemented tasks were included in the task string study. As a result of the pre-screening process, a great number of task combinations were eliminated. The detailed process of the pre-screening will be discussed further in Chapter 4.

3.2.3 Development of the Continuous Task String Models

The basic concept of the continuous task strings is to link the PCP tasks to relevant PE tasks. The task combinations pre-screened in the previous chapter were

further evaluated in terms of the logic of the continuous task strings. Theoretically, every task in previous phases needs to be linked to the tasks in a subsequent phase to achieve project goals effectively. Accordingly, the tasks during the pre-construction planning phase should be performed to plan and set up the systems for efficiently managing subsequent project execution tasks. In this regard, pre-construction planning tasks should be linked to relevant project execution tasks to effectively achieve project goals. To develop task string models, the author reviewed task combinations in terms of the logic of the continuous task string. In the continuous task string, the PCP task is needed to successfully implement the PE task. As a result, the pre-screened task combinations were all reviewed and classified into two groups: (1) continuous task strings, and (2) discontinuous task strings. The results of the classified task strings were further examined and assessed by a number of electrical professionals for verification purpose.

3.2.4 Validation of Task String Models

For the purpose of efficient model validation, a two-round survey was conducted. These rounds include: (1) confirmation of the discontinuous task strings, and (2) evaluation of the continuous task strings. This validation process used survey questionnaires to collect expert opinions regarding the task string models developed in the previous section. Due to the large number of task strings, each questionnaire was broken down into several segments.

In the first-round survey, task combinations, called discontinuous task strings, were evaluated by a number of electrical professionals in the U.S. Based on the result of the survey, the discontinuous task strings were confirmed and will not be required for further study. However, some of the discontinuous task strings assessed as logical by the experts were reclassified and added into continuous task string models, which were

further assessed during the second-round survey together with the pre-defined continuous task strings in the model development. Therefore, the first-round survey plays an integral role in the preparatory stage of the second-round survey.

The second-round survey was carried out to assess continuous task string models including the reclassified continuous task string models from the result of the first-round survey. Each string model was assessed by a number of electrical professionals in the U.S. The participants assessed the task string models in terms of the importance of the PCP task for successful implementation of the PE task. Based on the results of the survey, the continuous task string models were verified. During the second survey, the impact of task strings on project performance was also assessed to identify the relative importance of each task string on performance.

3.3 TASK STRING MODEL ANALYSIS

3.3.1 Overview of the Model Analysis

In the model analysis stage, the task string models were analyzed to investigate their effects on project performance in terms of cost and schedule success. Fifty sets of electrical project data were used in the analysis. As part of the analysis process, the continuous task string (TS) implementation score was calculated to measure the levels of task string implementation in electrical projects. Two main analyses were conducted: (1) the analysis of the relationship between task string efforts and project cost and schedule success; and (2) the analysis of the leveraged impact of task strings on project performance, compared to that of the corresponding individual PCP or PE task. Furthermore, the analysis also suggested the specific high-value task strings that are associated with project success in terms of cost and schedule performance.

3.3.2 Analysis of Task String Usage and Project Success Correlation

To evaluate the effects of task strings, the TS implementation effort was measured. The TS implementation score is a measure of the level of continuous task strings used in electrical projects. In the initial analysis, both weighted and unweighted task strings were used. To apply the relative importance of each task string, the weight of the task string was also computed by taking the average value of the importance of the task string on performance from the results of the second-round survey. By calculating the TS implementation score, electrical projects can be assessed in terms of the levels of task string implementation. To analyze the relationship between the levels of task string usage and project success, 50 electrical projects were used. Based on their performance, these projects were classified into two groups: (1) successful projects, and (2) unsuccessful projects. Using SPSS®15.0, an independent *t* test was conducted to determine the difference in the levels of task string implementation between successful projects and unsuccessful projects in terms of cost and schedule performance.

Independent Samples T Test

The independent samples *t* test is a statistical technique that is most widely used to determine mean difference between two independent groups. For the test to be performed, the dependent variables must be measured on an interval or ratio scale. The *t* test basically requires the following three assumptions:

- Normality: the dependent variable is normally distributed.
- Independence: two samples are independent of each other.
- Equal variance: the variances of the two populations are equal.

The t-test is reliable as long as the samples are reasonably symmetrical and bell-shaped, have equal numbers, and do not exhibit gross departures from a normal distribution. Therefore, the test is generally reliable, even for data that may not be entirely normal, so long as neither sample is greatly skewed.

By calculating a statistic, called *t-value*, the test assesses the null hypothesis that the two population means are equal to each other. The *t* statistic can be computed by the following formula:

$$t = \frac{x_1 - x_2}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}} \quad (3.1)$$

where, x_1,x_2=the means of the two samples, s_1^2, s_2^2=the variances of the two samples, and n_1,n_2=the sample sizes of the two samples.

During the independent samples *t* test, the null hypothesis was tested at the significance level of 0.05. The t-value calculated from the above formula can be compared to the critical t-value in terms of degrees of freedom. If the calculated t-value is greater than the critical t-value, the null hypothesis is rejected and as a result, the alternative hypothesis is accepted. Otherwise, the null hypothesis is proved. The two competing hypotheses are described below:

- H_0: ($\mu_f - \mu_s \geq 0$): The TS implementation score mean of project success is equal to or greater than that of project failure.
- H_A: ($\mu_f - \mu_s < 0$): The TS implementation score mean of project success is greater than that of project with failure.

3.3.3 Analysis of the Leveraged Effects of Task Strings on Performance

The leveraged effects of task strings were investigated to identify the extent to which performance can be improved by task string implementation as opposed to implementing either PCP or PE task individually. Fifty sets of electrical project data were used including task implementation of PCP and PE tasks, and project cost and schedule success. To compare the success rates of different task types (PCP-PE task strings, only PCP or PE tasks), several statistical analyses were used. These statistical methods include: (1) a one-way analysis of variance (ANOVA), (2) Kruskal Wallis H test, (3) Mann-Whitney U test, and (4) a binary logistic regression analysis.

Data Preparation

To compare the impact of the task string to that of its corresponding PCP and PE tasks, the validated continuity tasks were disassembled. As a result, three categories of project tasks were identified: (1) only PCP task; (2) only PE task; and (3) PCP-PE task string. In addition, the independent task implementation and its corresponding success rate for cost and schedule success were computed with the 50 electrical projects. Therefore, six continuous variables regarding cost and schedule success were identified. These variables include (a) cost and schedule success rates of the PCP task, (b) cost and schedule success rates of the PE task, and (c) cost and schedule success rates of the task string.

For the purpose of data quality, a small number of samples were removed. Too small sample sizes frequently yield unreliable results by increasing type I errors (α). In this analysis, if the frequency of any task included in the task string is less than five out of the 50 electrical projects, then the task string, including its corresponding PCP and PE tasks, was excluded from the analysis. If the minimum frequency for any cell in a

contingency table is less than five, the resulting χ^2 statistic may not be accurate (Rosenthal 1978; Yirmiya et al. 1989). Consequently, the task strings for which the frequency of each PCP and PE task is greater than or equal to five were considered for the analysis of the leveraged effect of the task string.

Analysis Method

Based on the probabilities of achieving successful outcomes, three groups were compared to identify the leveraged impact of task strings. These include task strings and their corresponding PCP and PE tasks. Eliminating task strings with less than 5 samples allowed the task strings to be analyzed with a one-way ANOVA test. If the data were not normally distributed, a non-parametric alternative, the Kruskal-Wallis one-way analysis of variance (ANOVA) test, was conducted. This analysis is a commonly used non-parametric test to determine the differences among multiple independent groups. For pair-wise comparisons, the Mann-Whitney U test was also used. The U-test, as a post-hoc test, is a non-parametric analysis that assesses whether or not two independent groups are different. To adjust multiple pair-wise comparisons, the Bonferroni correction was used.

To identify the leveraged effect of the specific task string on performance, a binary logistic regression analysis was conducted. The analysis is a powerful tool to identify group differences in probabilities when the dependent variable is dichotomous and the predictor variable is categorical. The results of the analysis identified the specific task strings that leverage performance as opposed to implementing either of their corresponding PCP or PE tasks individually. As a result, the odds ratio of a task string to its corresponding PCP or PE task was compared in order to identify whether the task string has significantly greater effects on performance than the PCP or PE task alone.

Kruskal-Wallis One-Way Analysis of the Variance (ANOVA)

The Kruskal-Wallis test is commonly used to determine whether *k* independent samples are drawn from different populations. Unlike the one-way analysis of variance (ANOVA) test, it is a non-parametric analysis. The ANOVA test generally makes three assumptions: independent samples, normal distributions, and equal variances. On the other hand, the Kruskal-Wallis test does not make any assumptions, except that the samples have an underlying continuous distribution with either a numeric or ordinal scale. It uses ranks by converting the values of the observations, instead of using the values of observations directly. For this reason, the test is sometimes called "one-way ANOVA on ranks."

The Kruskal-Wallis test assesses the null hypothesis that the samples do not differ in mean rank for the dependent variable. This null hypothesis is tested using the Kruskal Wallis test statistic, whose formula is defined below:

$$H = \frac{12}{N(N+1)} \times \sum_{i=1}^{k} \left(\frac{\mathrm{R}_i^2}{\mathrm{n}_i} \right) - 3(\mathrm{N}+1) \tag{3.2}$$

where, H=Kruskal-Wallis test, R_i=sum of the ranks for sample *i,* N=total number of observations in all samples, and n_i=the number of observations for sample *i.*

The Kruskal-Wallis test statistic is distributed similarly to a chi-square distribution with *k*-1 degrees of freedom where the sample size is greater than five. Therefore, if the Kruskal-Wallis test H is less than the chi-square value, then the null hypothesis will be accepted. If the Kruskal-Wallis test H is greater than the chi-square value, then the null hypothesis will be rejected.

Mann-Whitney U Test

Mann-Whitney is also a non-parametric test to determine whether there are any differences in outcomes between two independent samples. It is commonly used as an alternative to the independent samples *t*-test that assumes normal distribution and equal variances. Thus, it is the best test for comparing means when the dependent variable is not normally distributed and at least of ordinal scale. In general, the test compares medians of non-normal distributions between two independent groups. By calculating a statistic, called U, the test assesses the null hypothesis that the medians are equal between two samples. The U statistic for each group is calculated using the following formula:

$$\mathrm{U}_i = N_1 N_2 + \frac{N_i(N_i + 1)}{2} - R_i \tag{3.3}$$

where, N=the sample size for each group, and R_i=the sum of the ranks for each group.

In this study, the Mann-Whitney U test was used to conduct multiple comparisons as a post-hoc test after Kruskal-Wallis test. In the multiple pair-wise comparisons, the family wise type I error rate is usually increased. To adjust multiple pair-wise comparisons, Bonferroni's adjustment was applied. The adjustment ensures that family wise type I error rate is not greater than α. Therefore, two pair-wise comparisons were evaluated at the α/2 level of significance. Bonferroni's adjustment is calculated by the following formula:

$$P_{Bonf} = P_{Act} \times m \tag{3.4}$$

where, P_{Act}=actual P-value, P_{Bonf}=corrected P-value, and M=the total number of pair-wise comparisons.

The Binary Logistic Regression Analysis

The logistic regression model, also referred to as logit model, is commonly used in predicting the presence or absence of outcome with predictor variables (Powers and Xie 2008). In logistic regression, the dependent variable is usually dichotomous and the independent variables can take any form. Therefore, it does not need to be normally distributed like linear regression. The logit transformation (Johnson 1949) converts a probability measurement between 0 and 1 into any values in the interval (-∞, ∞). The logit transformation is defined as follows:

$$Logit(p) = ln\left[\frac{p}{1-p}\right] \tag{3.5}$$

where, *Logit(p)*=the natural log of the odds, *ln*=natural logarithm, and *p*=the probability of success.

After the dependent variable is transformed into a logit variable, it can be predicted by the independent variables using the maximum likelihood estimation. In the logistic regression model, the regression coefficients (β) can be interpreted as in linear models. Thus, β_k represents the change in the logit of the probability associated with a unit change in the k^{th} predictor holding all other predictors constant. The regression equation is described below:

$$logit(p) = b_0 + \beta_1 X_1 + \beta_2 X_2 + \ ... + \beta_k X_k \tag{3.6}$$

where, logit(p)=the log odds of the dependent variable, b_0=the constant, β_k= regression coefficient, and X_k=*k* independent variables.

3.3.4 Validation of the Effects of Task Strings Implementation

The effects of task string implementation were partially validated to demonstrate task strings contribute to project success. For this purpose, the effects of task string implementation on project success were investigated in terms of cost and schedule performance. The validation confirms which task strings contribute to project success. As a result, a list of the validated high-value task strings is presented with description of each.

3.4 SUMMARY OF RESEARCH METHODOLOGY

The research methodology was developed to outline the processes of the study. To obtain the research objectives, a detailed description of each step was also provided. In particular, several specific statistical methods were also illustrated for better understanding of different model analyses. In the final stage, the research was concisely summarized with the findings of the study and it also provided evidence to support the research hypotheses. Furthermore, recommendations for future research were also suggested to expand the current research. The research is concluded with a summary of contributions to practice and the project management body of knowledge.

SECTION II: MODEL FORMULATION

Chapter 4: Data-Based Pre-Screening

4.1 Overview of Data-Based Pre-Screening

The primary purpose of this study is to investigate task strings that pairs pre-construction planning tasks with relevant project execution tasks for electrical contractors to achieve significantly better performance. A total of 3,910 possible task combinations were created from 46 PCP tasks and 85 PE tasks in previous studies. However, this excessively large number of combinations would cost enormous time and effort to analyze. Therefore, a pre-screening was conducted to achieve robust and reliable results by eliminating statistically insignificant tasks.

Prior to the pre-screening process, task implementation and its corresponding success rate were computed based on 50 electrical projects. The pre-screening process investigated the patterns of data, including (1) percent task implementation and (2) project success rate. Based on these two criteria, the PCP and PE tasks were reviewed and analyzed. As a result of the process, a great number of inappropriate PCP and PE tasks were screened out. Figure 4.1 shows the pre-screening process for the PCP/PE task string study.

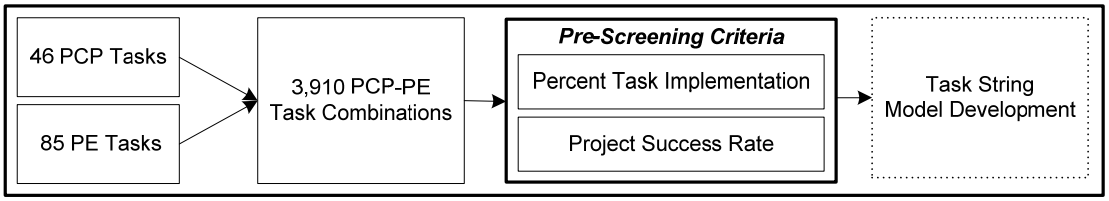

Figure 4.1: Data-Based Pre-Screening Process.

4.2 DATA PREPARATION

In the previous study, Nasr (2009) collected 50 electrical construction projects. The data collection process integrated face-to-face interviews and survey questionnaires. A total of 25 contractors across the U.S. participated in the comprehensive site visits and provided two recently completed projects: one successful and one less-than-successful project. As a result, 50 sets of electrical project data were obtained. These data mainly consist of task implementation of PCP and PE tasks and other important information on project performance. These projects were summarized in terms of project type, subcontract cost, duration, and work hours as shown in Table 4.1.

Characteristics	Classes	Number of Project (Total N=50)	% Mix of Projects
Project Type	Industrial	18	36%
	Institutional	14	28%
	Commercial/Other	18	36%
Subcontract Cost	< $1M	20	40%
	$1M – $3M	16	32%
	> $3M	14	28%
Duration	< 52 weeks	30	60%
	> 52 weeks	20	40%
Work Hours	< 7,500 hours	15	30%
	> 10,000 hours	19	38%
	> 20,000 hours	16	32%

Table 4.1: Mix of 50 Electrical Projects.

In 50 projects, PCP tasks were implemented by 26% to 100% while, PE tasks were performed by 8% to 100%. Tables 4.2-3 show the percent PCP and PE task implementation in 50 electrical projects.

PCP task #	% task implementation	PCP task #	% task implementation	PCP task #	% task implementation	PCP task #	% task implementation
1	0.98	13	0.98	25	0.90	37	0.26
2	0.66	14	0.86	26	0.90	38	0.60
3	0.82	15	0.90	27	0.76	39	0.90
4	0.88	16	0.94	28	0.96	40	1.00
5	0.98	17	0.98	29	0.94	41	0.96
6	0.98	18	0.26	30	0.82	42	0.94
7	0.84	19	0.96	31	0.74	43	0.98
8	0.86	20	0.98	32	0.42	44	0.98
9	0.80	21	0.98	33	0.92	45	0.94
10	0.66	22	0.90	34	0.88	46	0.94
11	0.76	23	0.98	35	0.98		
12	0.72	24	0.96	36	0.92		

Table 4.2: Percent PCP Task Implementation.

PE task #	% task implementation	PE task #	% task implementation	PE task #	% task implementation	PE task #	% task implementation
1	0.76	23	0.78	45	0.72	67	0.34
2	0.76	24	0.34	46	0.54	68	0.52
3	0.90	25	0.70	47	0.50	69	0.96
4	0.88	26	0.50	48	0.36	70	0.92
5	0.94	27	0.68	49	0.44	71	0.08
6	0.50	28	0.82	50	0.40	72	0.72
7	0.82	29	0.66	51	0.88	73	0.54
8	0.76	30	0.32	52	0.50	74	0.84
9	0.62	31	0.70	53	0.92	75	0.18
10	0.80	32	0.82	54	0.68	76	0.38
11	0.78	33	0.68	55	1.00	77	0.56
12	0.64	34	0.82	56	0.50	78	0.52
13	0.42	35	0.68	57	0.56	79	0.82
14	0.90	36	0.28	58	0.52	80	0.40
15	0.38	37	0.60	59	0.28	81	0.30
16	0.14	38	0.98	60	0.64	82	0.82
17	0.54	39	0.64	61	0.52	83	0.88
18	1.00	40	0.58	62	0.48	84	0.84
19	0.80	41	0.88	63	0.68	85	0.88
20	1.00	42	0.72	64	0.76		
21	0.88	43	0.76	65	0.78		
22	0.70	44	0.68	66	0.70		

Table 4.3: Percent PE Task Implementation.

The performance data was also transformed to calculate success rate, with projects classified into successful and unsuccessful outcomes in terms of cost and schedule. A successful project is basically defined as a project that achieved planned outcomes; otherwise, it is called an unsuccessful project. To transform values of project performance into binary values, 0 and 1 (0=unsuccessful and 1=successful), the following metrics, shown in Table 4.4, were used:

#	Performance	Metrics	Assessed Success	
			Successful	Unsuccessful
1	Cost	Budgeted Cost – Actual Cost	either 0 or greater than 0	less than 0
2	Schedule	(Estimated Duration +Time Extension Granted) – Actual Duration	either 0 or greater than 0	less than 0

Table 4.4: Transformation of Project Performance.

As a result, of the 50 electrical construction projects 30 were classified as successful in cost, and 42 in schedule. The results show that relatively greater success was achieved in schedule, which was caused by the fact that most of them were schedule-driven projects in which electrical contractors mainly work as subcontractors. Furthermore, general contractors can force electrical subs to accelerate schedule even if not their fault. Electrical contractors may or may not get paid for extra acceleration costs. Therefore, the projects achieved more success in schedule than in cost.

4.3 DATA-BASED PRE-SCREENING

The data-based pre-screening process determines the initial eligibility of PCP and PE tasks, taking into account the mode of task implementation and related project success. In this pre-screening process, 50 sets of electrical project data that were recently

completed throughout the United States were used. To achieve robust and reliable results, two main criteria were applied: (1) percent task implementation, and (2) project success rate in terms of cost and schedule performance. Based on these two criteria, seven task groups were suggested as shown in Table 4.5. These seven task groups, (A), (B), (C), (D), (E), (F), and (G) represent the simple effect of PCP and PE tasks on project success by percent of task implementation. For a task string study, only tasks that fell into the range of 50-85% task implementation and also achieved a project success rate of greater than 50% [task group (D)] are used.

Task Group	% PCP Task Implementation (TI)	# of PCP Tasks	Set Function	% PE Task Implementation (TI)	# of PE Tasks	Set Function	Cost / Schedule Success Rate	# of Task Combinations
A	TI>85%	32	and	TI>85%	16	and	Greater than 50%	512
B	TI>85%	32	and	50%<TI≤85%	47	and	Greater than 50%	1,504
C	50%<TI≤85%	11	and	TI>85%	16	and	Greater than 50%	176
D	50%<TI≤85%	11	and	50%<TI≤85%	47	and	Greater than 50%	517
E	TI>50%	43	and	TI≤50%	22	and	Greater than 50%	946
F	TI≤50%	3	and	TI>50%	63	and	Greater than 50%	189
G	TI≤50%	3	and	TI≤50%	22	and	Greater than 50%	66

Table 4.5: Task Groups by Percent Task Implementation and Success Rate.

The tasks in task group (D) are moderately implemented and more appropriate to achieve robust and reliable results, while those tasks in the other task groups are not meaningful to investigate the unique effect of task strings because they are too frequently or too rarely implemented. For example, if tasks were implemented less than 50% of the 50 projects, they do not provide enough information for task string study. On the other

hand, if tasks were implemented more than 85% of the projects, these tasks were too frequently performed, and as a result, they show a strong independent effect on performance. Therefore, task groups (A), (B), (C), (E), (F), and (G) are not considered in the task string study but they still need to be investigated in the future study.

Task group (A) includes PCP tasks and PE tasks that were implemented in more than 85% of the 50 projects and achieved a project success rate of greater than 50%. These tasks were too frequently implemented by a majority of contractors. These tasks may therefore be regarded as basic tasks, effective in achieving project success. However, the tasks in task group (A) are meaningless for a task string study because the tasks are too frequently implemented by a majority of contractors, and as a result, they have a greater possibility of making unnecessary combinations with each other in task strings. Therefore, it is difficult to identify the leveraged effect of the task strings on project success with these tasks compared to either that of PCP or PE tasks. Furthermore, these tasks are believed to have an independent impact on project success regardless of their combinations.

Task group (B) is made up of PCP tasks that were implemented in more than 85% of the 50 projects and PE tasks that were implemented in more than 50% and less than or equal to 85% of the projects. These tasks achieved a project success rate of greater than 50%. In this group, because PCP tasks were too frequently performed by a majority of electrical contractors, they might be regarded as basic tasks, effective in achieving project success. Furthermore, the PCP tasks are also believed to have an independent impact on project success regardless of succeeding PE tasks. Thus, it is difficult to identify the leveraged effect of the task strings on project success because they do not provide a fair number of independent PE tasks due to the dominant number of PCP tasks. Moreover, the

PE tasks are also believed to have an independent impact on project success regardless of their combinations.

Task group (C) consists of PCP tasks that were implemented in more than 50% and less than or equal to 85% of the 50 projects and PE tasks that were implemented in more than 85% of the 50 projects. In this task group, PE tasks were too frequently performed by a majority of electrical contractors and as a result, it is difficult to identify the leveraged effect of the task strings on projects success because they do not provide a fair number of independent PCP tasks due to the dominant number of PE tasks. Based on the same rationale used to eliminate group (B), the tasks in task group (C) are also not considered for this task string study.

Task groups (E), (F), and (G) comprise either PCP or PE tasks that were implemented in less than or equal to 50% of the projects and achieved a project success rate of greater than or equal to 50%. These tasks were less frequently implemented by electrical contractors, but they achieved greater than 50% project success. These tasks might not be well-known to other contractors, or their effectiveness in achieving project success may be uncertain. These tasks are also excluded in the task string study because they do not provide enough information. This exclusion does not mean there are no relationships between the PCP and PE tasks. However, these tasks cannot adequately demonstrate the effect of the task strings between PCP and PE tasks because they do not represent a fair number of task implementations to identify such task strings.

Task group (D) consists of PCP and PE tasks that were implemented in more than 50% and less than or equal to 85% of projects and at the same time achieved a project success rate of greater than 50%. These tasks are moderately implemented by electrical contractors, and, as a result, these tasks might be appropriate to achieve robust and reliable results for a task string study. Therefore, only tasks that are moderately

performed (11PCP tasks and 47 PE tasks) in task group (D) are used for further study of task strings. Figure 4.2 shows a graphical representation of the number of PCP and PE tasks in task group (D).

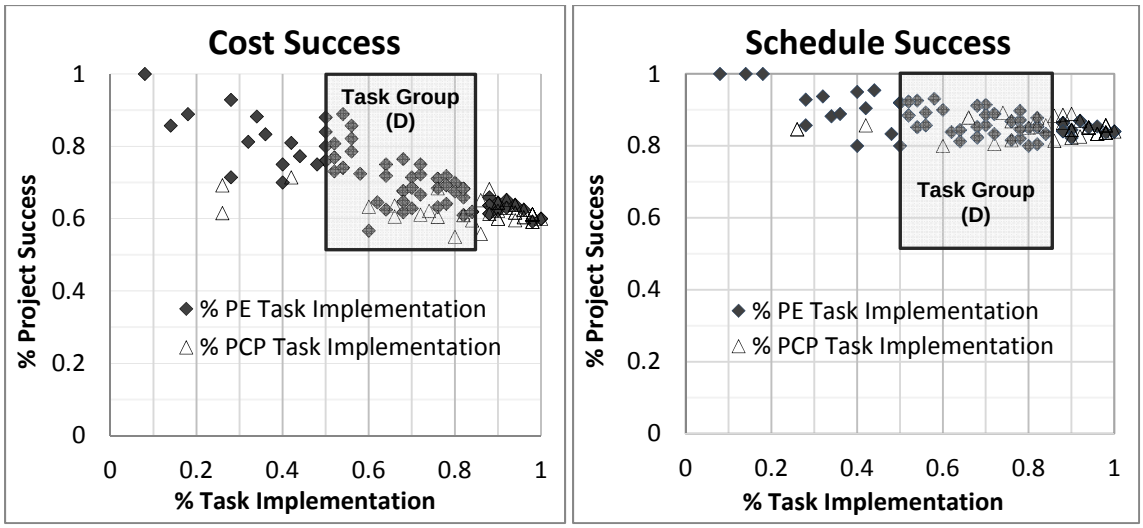

Figure 4.2: Matrix Plots of the Selected 11 PCP and 47 PE Tasks.

As a result of the data-based pre-screening process, 3,910 task combinations, with 46 PCP and 85 PE tasks, were categorized into seven task groups: task groups (A), (B), (C), (D), (E), (F), and (G). Task group (A) includes 512 task combinations; task group (B) includes 1,504 task combinations; task group (C) includes 17 task combinations; task group (D) includes 517 task combinations; task group (E) includes 946 task combinations; task group (F) includes 189 task combinations; and task group (G) includes 66 task combinations. By eliminating inappropriate task combinations, the PCP and PE tasks in task group (D) were selected to use for further study of task strings. These tasks, including 11 PCP tasks and 47 PE tasks, fell into the 50-85% task implementation range and achieved a project success rate of greater than 50% in terms of cost and schedule.

4.4 SUMMARY OF DATA-BASED PRE-SCREENING

The pre-screening process determines the 11 PCP tasks and 47 PE tasks to be used for cost and schedule success by eliminating 35 PCP tasks and 38 PE tasks. These tasks comprise 517 possible task combinations that will be used for further analysis of task strings. Figure 4.3 summarizes the data-based pre-screening process and the selected number of PCP and PE tasks for further analysis in the task string study. The selected 11 PCP tasks and 47 PE tasks in task group (D) are presented in Tables 4.6-7. The eliminated task combinations in other groups were also presented in Appendix A.

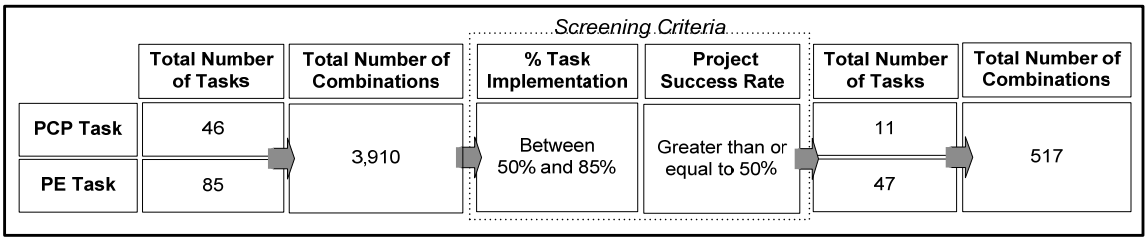

Figure 4.3: Summary of Data-Based Pre-Screening.

PCP #	Pre-Construction Planning Tasks
2	Hold turnover meeting between estimator and project manager (when applicable)
3	Hold separate turnover meeting between project manager and field supervisor
7	Field supervisor reviews plans, specifications, and schedule
9	Conduct site visit
10	Compare estimated (bid) work activities & materials to planned performance
11	Identify value engineering and prefabrication opportunities and how to simplify the work
12	Prepare construction takeoff
27	Develop, review, or expand cost code scheme
30	Develop installation sequence and layout drawings
31	Develop field instructions, including panel, pull, or conduit schedules
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project

Table 4.6: Selected 11 PCP Tasks for Task Strings.

#	Project Execution Tasks
1	Setup office trailer in a timely manner and in a convenient location
2	Setup storage trailer and lay down area
7	Make sure the foreman has everything he or she needs to get started
8	Make use of a project file
9	Use a documentation control system
10	Use an RFI tracking and processing system
11	Use a change order tracking and processing system
12	Keep all schedule documentation, including delays
17	Review bid documents for materials and vendors and any vendor responsibilities
19	Establish delivery dates
22	Ensure good material handling on site
23	Communicate all material information to field
25	Lock in the needed prices
27	Make sure the invoice matches the material costs
28	Review contract drawing, specifications, and the bid for any special needs
29	Schedule deliveries and pickups
31	Review the scope and determine the subcontractors' scope of work
32	Establish subcontracts
33	Determine the subcontractors' schedule
34	Request submittals and shop drawings
35	Inform the field about the subcontractors and the people to contact
37	Make sure the subcontractors are licensed and are capable of doing the job
39	Identify safety issues with the existing job and specific job activities
40	Plan for any additional needs for safety equipment
42	Perform job walks to ensure that the safety rules are being followed
43	Receive support from the company CEO/VP
44	Communicate constantly with the foreman, especially when problems occur
45	Communicate constantly with the vendors and subcontractors
46	Communicate constantly with the General Contractor and Owner
54	Track change orders
57	Review the schedule and identify milestone dates
58	Identify work that impacts electrical activity
60	Review the schedule with the field
61	Update the schedule regularly
63	Use cost codes (Cost breakdown)

Table 4.7: Selected 47 PE Tasks for Task Strings.

#	Project Execution Tasks
64	Track labor costs
65	Track material and subcontractor costs
66	Include issued change orders
68	Compare the project costs to the budget
72	Make sure that the field is aware of the quality needed
73	Check the quality of installation through site visits
74	Perform test results/commissioning
77	Maintain the correct crew mix and manpower level
78	Ensure labor hours are turned in
79	Ensure that all punch list items are signed off on
82	Ensure that all change orders and purchase orders are closed
84	Turn all project closeout documents over to the General Contractor

Table 4.7: Selected 47 PE Tasks for Task Strings (Continued).

Chapter 5: Development of PCP/PE Task String Models

5.1 Overview of Task String Model Development

In the previous data-based pre-screening process, 517 task combinations between pre-construction planning and project execution were identified, including 11 PCP tasks and 47 PE tasks. To develop continuous task string (TS) models between PCP and PE, the relationship between PCP and PE tasks in each combination was reviewed. For the purpose of efficient evaluation of those combinations, the author evaluated each combination in terms of the continuous task string logic that describes the importance of completing the PCP task in order to successfully execute the PE tasks. As a result of the evaluation, 517 task combinations were categorized into two string groups: (1) discontinuous task strings, and (2) continuous task strings. This preliminary evaluation of task combinations was subsequently reviewed by electrical professionals to verify the preliminary results. This will be discussed further in section 5.4. Figure 5.1 summarizes the process of the PCP-PE task string model development.

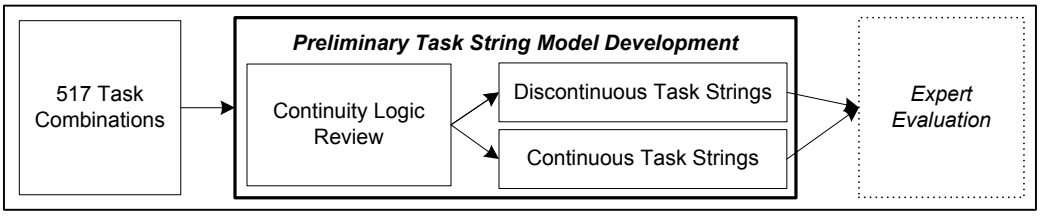

Figure 5.1: Logic-Based Task String Model Development.

5.2 Development of Hypothesis

The primary purpose of this study was to investigate the effects of PCP-PE task strings on project performance. To develop continuous task string models, PCP tasks

were linked to relevant PE tasks. During the development of task string models, hypothesis I was developed to test the relationship between PCP and PE tasks. This hypothesis ultimately answers the first research question. Table 5.1 summarizes the research question and its corresponding hypothesis.

#	Research Question	Hypothesis
I	Which PCP tasks are needed for successful implementation of PE tasks?	PCP tasks are needed for successful implementation of PE tasks.

Table 5.1: Research Questions and Hypotheses.

5.3 LOGIC OF THE CONTINUOUS TASK STRINGS BETWEEN PCP AND PE

Pre-construction planning tasks are inherently associated with project execution tasks because planning tasks are basically used to plan and set up the systems for efficiently managing subsequent project execution tasks. Accordingly, both relevant planning and execution tasks should be implemented continuously in a project for effective project management. These task combinations of planning and execution are defined as *task strings* between pre-construction planning and project execution. For example, the material handling plan at the pre-construction planning phase establishes processes for ordering, receiving, staging, and storing major materials and equipment on the job site. This planning task is closely associated with material management tasks at the execution phase that include checking material packaging, labels, delivery, and so on. Consequently, the material handling plan should be performed to effectively implement material management tasks. In that case, those two tasks are called *a continuous task string* between pre-construction planning and project execution. On the other hand, if the

planning task is not related to the execution task, those two tasks are called as *a discontinuous task string* between PCP and PE. Figure 5.2 shows the examples of continuous and discontinuous task strings between pre-construction planning and project execution.

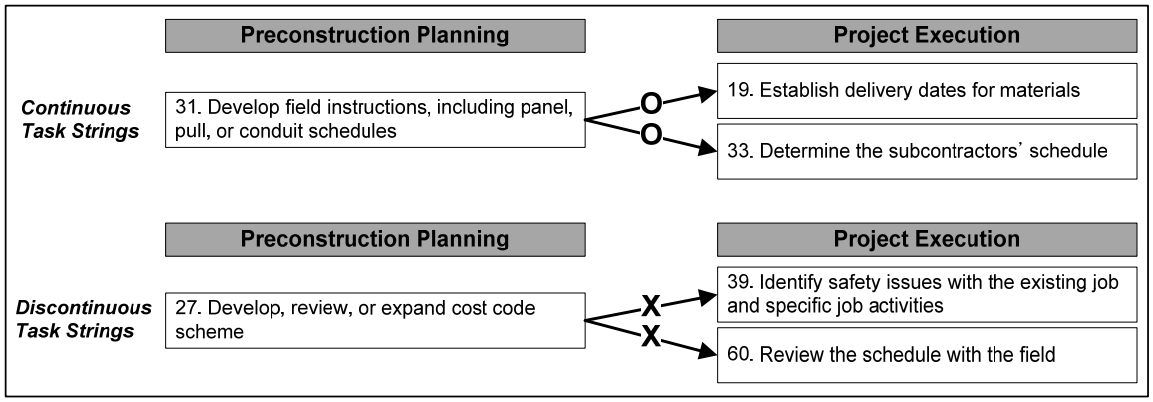

Figure 5.2: Examples of Continuous and Discontinuous Task Strings.

5.4 DEVELOPMENT OF THE CONTINUOUS TASK STRING MODELS

With the 11 PCP tasks and 47 PE tasks, 517 task combinations were identified after the pre-screening process. To develop task string models, the author reviewed task combinations in terms of the logic of the continuous task string. The logic review hypothetically examined the relationship between PCP tasks and the corresponding PE tasks. In the continuous task strings, the PCP task is needed to effectively implement the PE task. Based on the concept of the logic, the author can identify a number of reasonable task pairs in which PCP tasks are needed to implement the subsequent PE tasks.

To assess the logic of 517 task combinations, the author evaluated which PCP tasks are needed for successful implementation of the PE task. Each PE task was tested

with 11 PCP tasks in terms of the task string logic. Thus, all 47 PE tasks were hypothetically examined with 11 PCP tasks. Figure 5.3 shows the excerpt from the spreadsheets that were used for the task string logic review.

PE Task 22	Implement an effective material handling system on site		
PCP Task#	**Pre-Construction Planning Task**	**Logical**	**Illogical**
2	Hold turnover meeting between estimator and project manager		X
3	Hold separate turnover meeting between project manager and field supervisor		X
7	Field supervisor reviews plans, specifications, and schedule	X	
9	Conduct site visit	X	
10	Compare estimated (bid) work activities & materials to planned performance	X	
11	Identify value engineering and prefabrication opportunities and how to simplify the work		X
12	Prepare construction takeoff		X
27	Develop, review, or expand cost code scheme		X
30	Develop installation sequence and layout drawings	X	
31	Develop field instructions, including panel, pull, or conduit schedules	X	
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	X	

PE Task 23	Communicate all material information to field personnel		
PCP Task#	**Pre-Construction Planning Task**	**Logical**	**Illogical**
2	Hold turnover meeting between estimator and project manager		X
3	Hold separate turnover meeting between project manager and field supervisor		X
7	Field supervisor reviews plans, specifications, and schedule	X	
9	Conduct site visit		X
10	Compare estimated (bid) work activities & materials to planned performance	X	
11	Identify value engineering and prefabrication opportunities and how to simplify the work		X
12	Prepare construction takeoff	X	
27	Develop, review, or expand cost code scheme		X
30	Develop installation sequence and layout drawings	X	
31	Develop field instructions, including panel, pull, or conduit schedules	X	
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	X	

Figure 5.3: Sample Spreadsheet (excerpt) for Task String Logic Review.

Based on the relationship between the PCP tasks and each PE task, the task combinations were classified into two categories: logical or illogical relationship. A logical relationship means the PCP task is needed to successfully implement the subsequent PE task, while an illogical relationship does not provide a meaningful association between PCP and PE tasks. As a result, 517 task combinations were categorized into 155 logical task combinations and 362 illogical task combinations. Among the task combinations, those combinations in the logical relationship category were considered as continuous task strings. On the other hand, the others were regarded as discontinuous task strings. Therefore, the preliminary task string models consist of 155 logical task combinations between PCP and PE tasks. Table 5.2 describes the number of task strings within each PCP task-to-PE group.

Group #	PCP task-to-PE group	# of preliminary task string models	# of related PCP tasks	# of related PE tasks
1	Mobilization	10	5	3
2	Document Management	6	2	5
3	Material Management	31	10	6
4	Tool Management	10	7	2
5	Subcontractor Management	32	11	5
6	Safety Management	11	5	3
7	Communication	1	1	1
8	Scope & Change Control	1	1	1
9	Scheduling	18	8	4
10	Cost Control & Billing	18	5	5
11	Quality Management	7	3	3
12	Labor Management	7	6	2
13	Project Closeout	3	1	3

Table 5.2: Results of Preliminary Task String Model Development.

The preliminary task string models were classified into 13 PCP task-to-PE groups according to the PE task categories. These groups include: (1) mobilization, (2) document management, (3) material management, (4) tool management, (5) subcontractor management, (6) safety management, (7) communication, (8) scope and change control, (9) scheduling, (10) cost control and billing, (11) quality management, (12) labor management, and (13) project closeout.

The specific task strings with their corresponding PCP and PE tasks are graphically presented in Figures 5.4-16. The task strings in which the PCP tasks need to be implemented to successfully implement the subsequent PE tasks are presented with arrows. The task string models for mobilization consisted of five PCP tasks and three PE tasks. As a result, ten task string models were developed for mobilization. Figure 5.4 describes the task string models for mobilization.

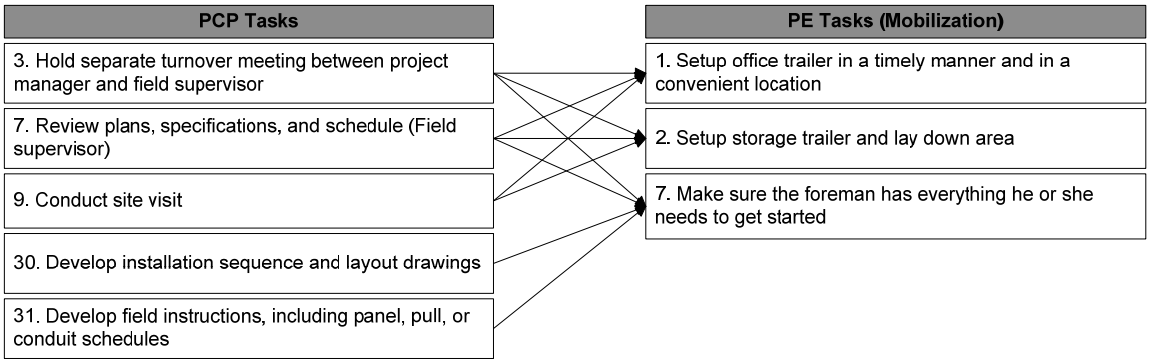

Figure 5.4: Task String Models for Mobilization.

The task string models for document management included five PE tasks and two PCP tasks. The two PCP tasks were hypothetically connected to the relevant PE tasks. As a result, six task string models were suggested for document management. Figure 5.5 describes the task string models for document management.

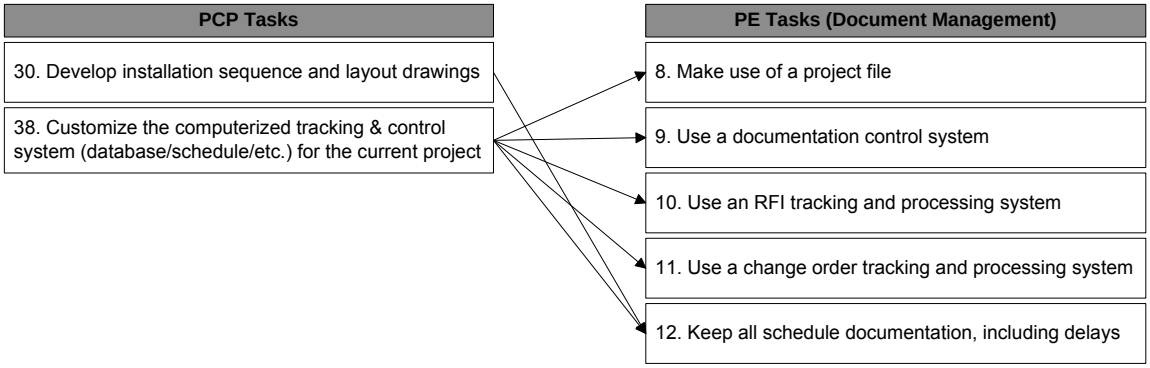

Figure 5.5: Task String Models for Document Management.

The task string models for safety management consisted of five PCP tasks and three PE tasks. These PCP tasks were connected to the relevant PE tasks. As a result, eleven task string models for safety management were proposed. Figure 5.6 presents the task string models for safety management.

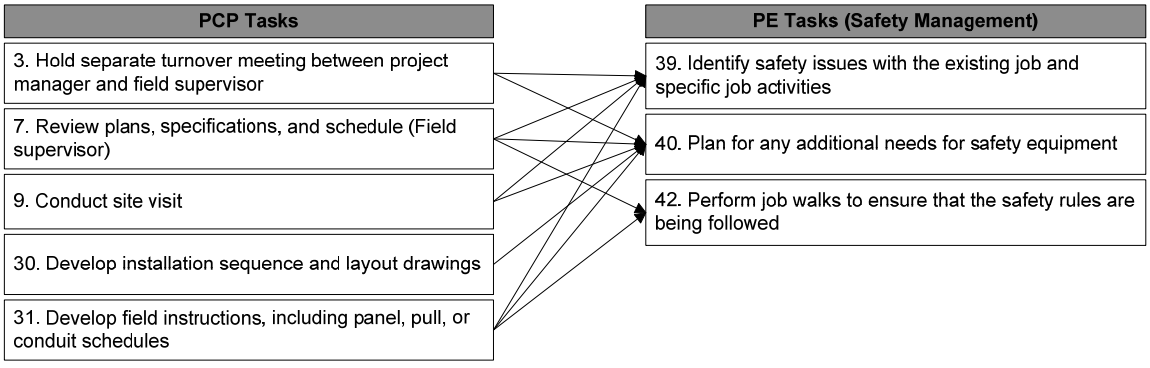

Figure 5.6: Task String Models for Safety Management.

The task string models for material management included ten PCP tasks and six PE tasks. These PCP and PE tasks were intimately connected to one another. As a result, thirty-one task string models for material management were proposed. Figure 5.7 describes the task string models for material management.

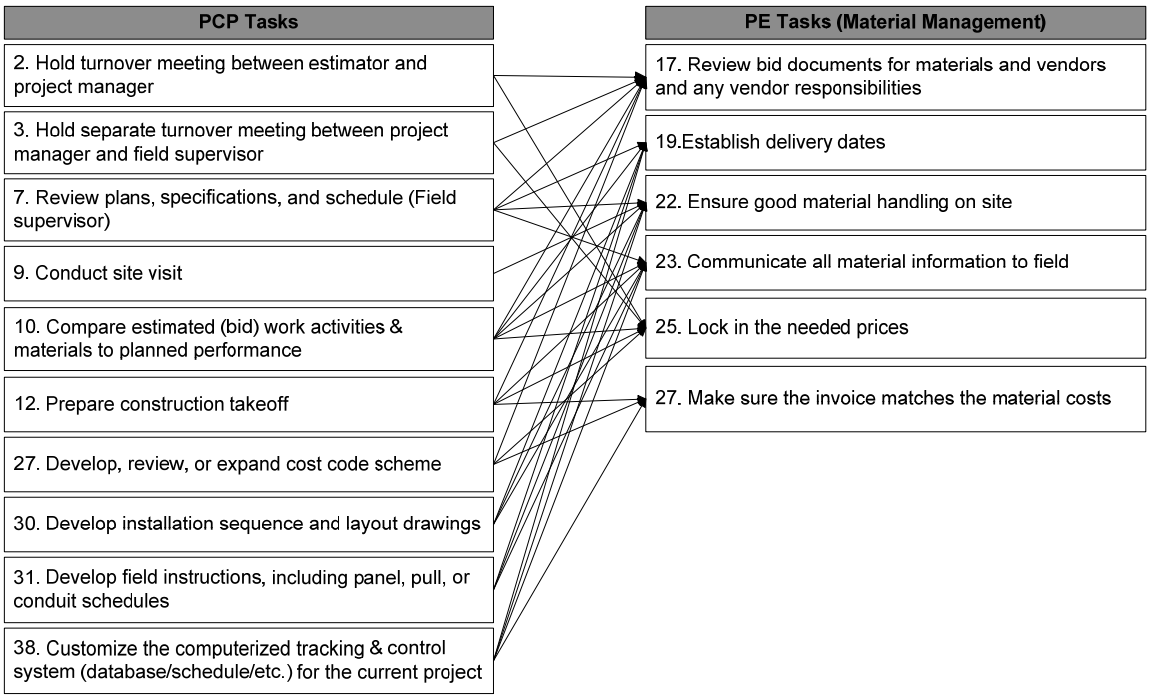

Figure 5.7: Task String Models for Material Management.

The task string model for communication consisted of only one PCP task and one PE task. As a result, only one task string model was suggested for communication. The string model is presented in Figures 5.8.

Figure 5.8: Task String Models for Communication.

The task string models for tool management included seven PCP tasks and two PE tasks. The PCP tasks were linked to the relevant PE tasks. As a result, ten task string models for tool management were recommended. Figure 5.9 presents the task string models for tool management.

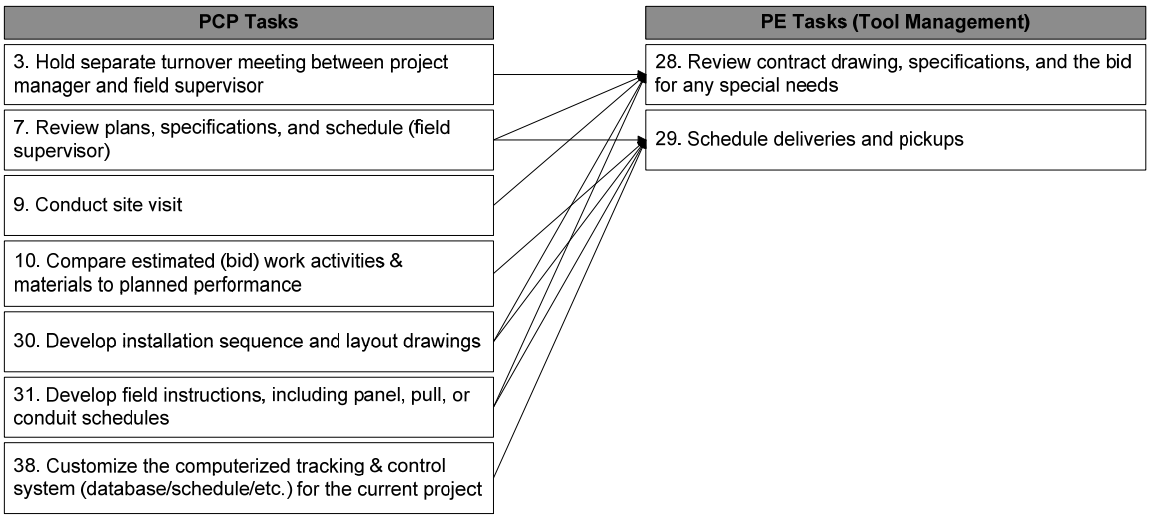

Figure 5.9: Task String Models for Tool Management.

The task string models for cost control and billing were comprised of five PCP tasks and five PE tasks. These PCP tasks were combined with the relevant PE tasks. As a result, eighteen task string models were proposed for cost control and billing. The task string models for cost control and billing are shown in Figure 5.10.

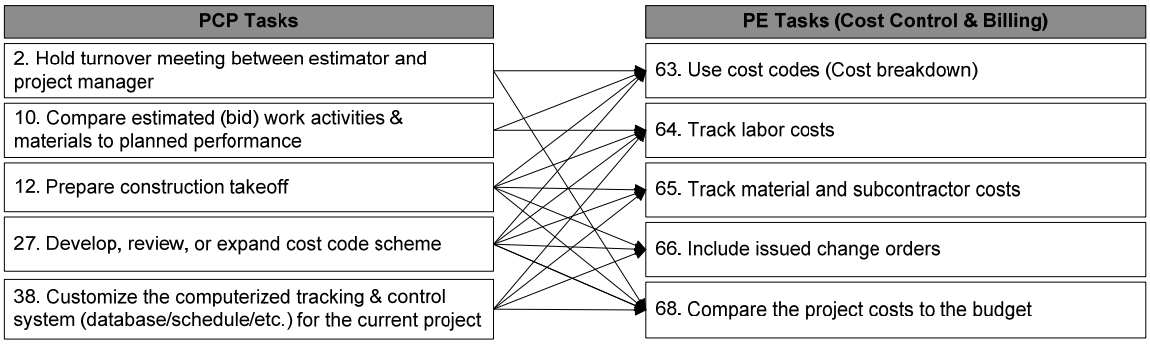

Figure 5.10: Task String Models for Cost Control and Billing.

The task string models for subcontractor management included eleven PCP tasks and five PE tasks. The PE tasks were connected to the related PCP tasks. As a result, thirty-two task string models for subcontractor management were suggested. Figure 5.11 describes the task string models for subcontractor management.

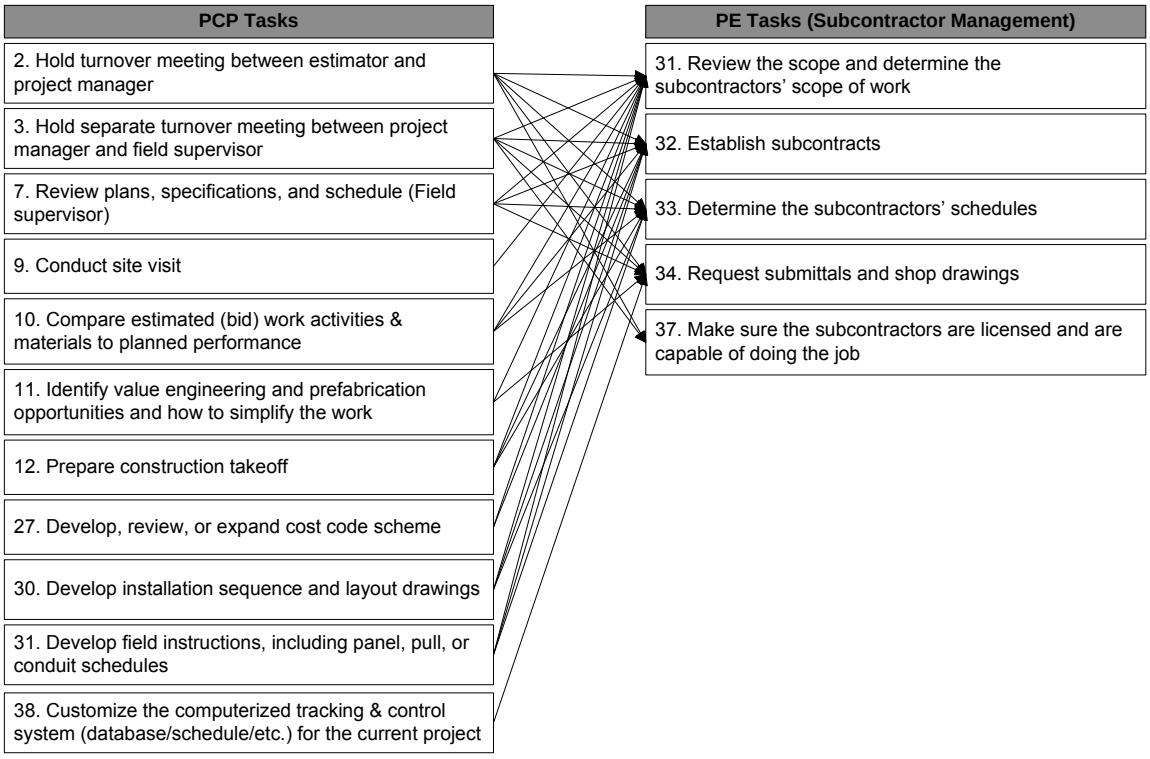

Figure 5.11: Task String Models for Subcontractor Management

The task string model for scope and change control consisted of only one PCP task and one PE task. As a result, only one task string model was suggested for scope and change control. The string models are presented in Figures 5.12.

Figure 5.12: Task String Model for Scope and Change Control.

The task string models for scheduling included eight PCP tasks and four PE tasks. These PCP tasks were linked to the relevant PE tasks. As a result, eighteen task string models were suggested for scheduling. Figure 5.13 shows the task string models for scheduling.

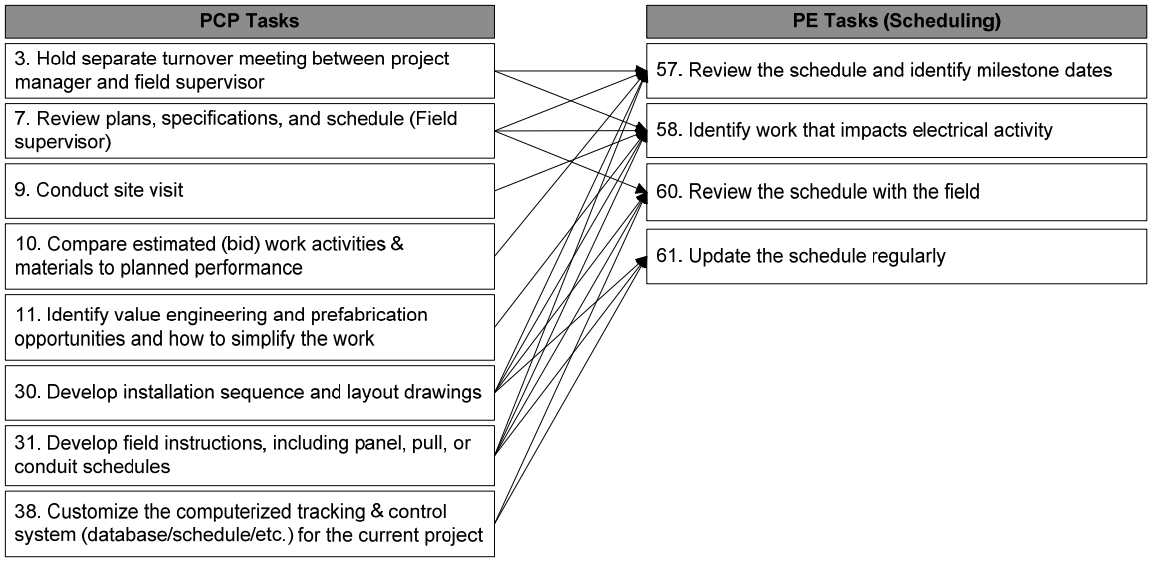

Figure 5.13: Task String Models for Scheduling.

The task string models for quality management consisted of three PCP tasks and three PE tasks. These PCP tasks were connected to the relevant PE tasks. As a result, seven task string models were proposed for quality management. Figure 5.14 describes the task string models for quality management.

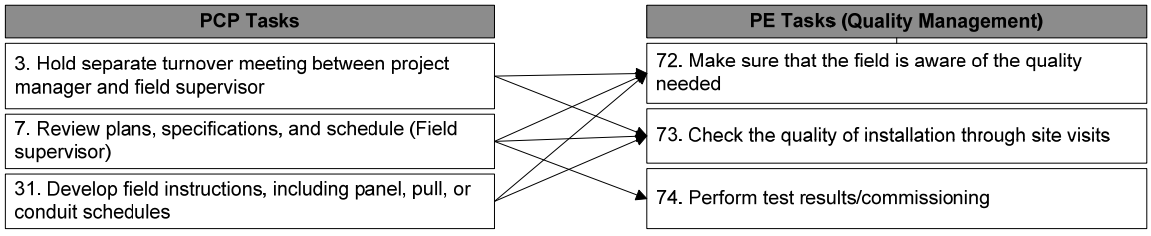

Figure 5.14: Task String Models for Quality Management.

The task string models for labor management included six PCP tasks and two PE tasks. These PCP tasks were connected to the relevant PE tasks. As a result, seven task string models were proposed for labor management. Figure 5.15 graphically presents the task string models for labor management.

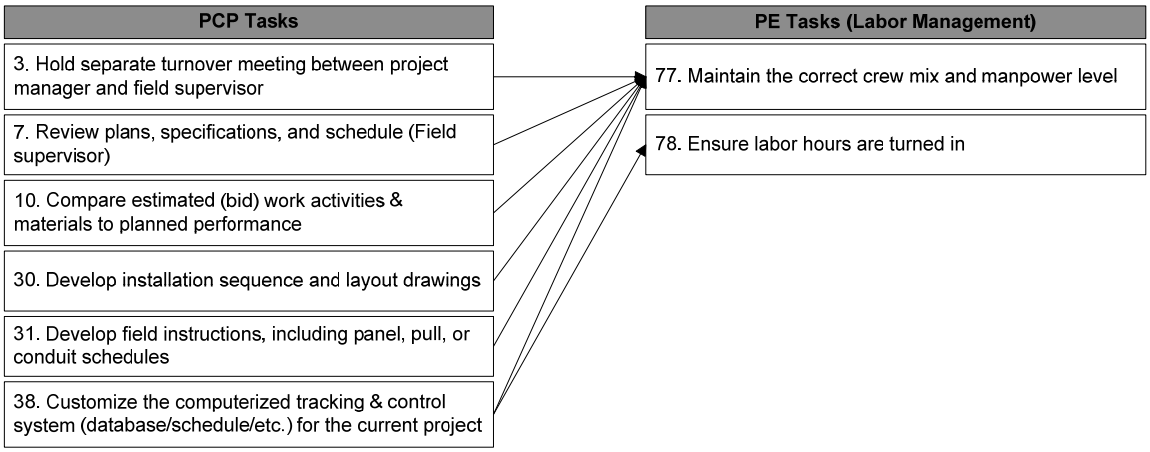

Figure 5.15: Task String Models for Labor Management.

The task string models for project closeout were comprised of one PCP task and three PE tasks. The PCP task was linked to the three PE tasks. As a result, three task string models were suggested for project closeout. Figure 5.16 shows the task string models for project closeout.

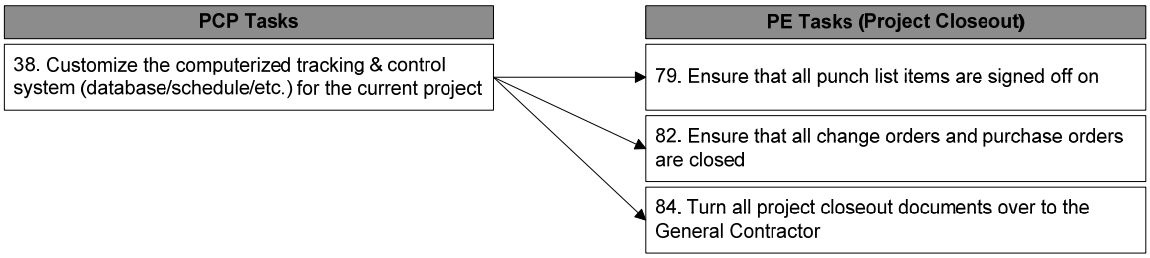

Figure 5.16: Task String Models for Project Closeout.

5.5 SUMMARY OF PRELIMINARY TASK STRING MODELS

The preliminary task string models were developed based on the author's knowledge of and opinion on project management. As a result, 155 continuous task strings were identified and 362 task combinations were classified as discontinuous task strings, which were discarded as illogical relationships after validation. The summary of the continuous task string models is described in Table 5.2. These preliminary task string models are somewhat subjective. Therefore, these models, including 155 continuous and 362 discontinuous task strings, were further verified by a number of electrical professionals.

PE Task Category	Total # of Task Strings	Related PCP Task #	Related PE Task #
Mobilization	10	3, 7, 9, 30, 31	1, 2, 7
Document Management	6	30, 38	8, 9, 10, 11, 12
Material Management	31	2, 3, 7, 9, 10, 12, 27, 30, 31, 38	17, 19, 22, 23, 25, 27
Tool Management	10	3, 7, 9, 10, 30, 31, 38	28, 29
Subcontractor Management	32	2, 3, 7, 9, 10, 11, 12, 27, 30, 31, 38	31, 32, 33, 34, 37
Safety Management	11	3, 7, 9, 30, 31	39, 40, 42
Communication	1	38	43
Scope & Change Control	1	38	54
Scheduling	18	3, 7, 9, 10, 11, 30, 31, 38	57, 58, 60, 61
Cost Control & Billing	18	2, 10, 12, 27, 38	63, 64, 65, 66, 68
Quality Management	7	3, 7, 31	72, 73, 74,
Labor Management	7	3, 7, 10, 30, 31, 38	77, 78
Project Closeout	3	38	79, 82, 84

Table 5.3: Summary of Preliminary Task String Models.

Chapter 6: Validation of Task String Models

6.1 Validation Process Using Expert Opinion-Based Surveys

For the purpose of validating the task string models between PCP and PE, an opinion-based survey was used to gather information on the logic of the continuous task strings. This process used survey questionnaires designed to verify the task string models. A nationwide survey was conducted between Sep. 2010 and May 2011. A total of 57 responses were collected by email-based surveys. These responses represented 7 major metropolitan areas in 4 U.S. states. For an efficient validation process, a two-round survey was structured: (1) confirmation of discontinuous task strings, and (2) evaluation of continuous task strings. The first round survey plays an integral role in the preparatory stage for the second round survey. Therefore, the second-round survey was carried out by updating the continuous task strings based on the results of the first-round survey. The validation process of the task string models is presented below in Figure 6.1. As a result of validation, hypothesis I was tested and the results were summarized.

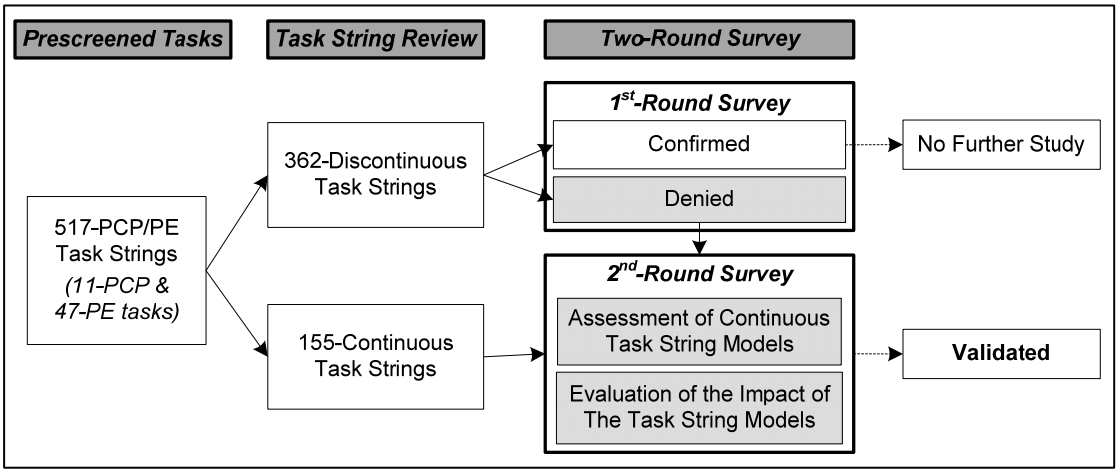

Figure 6.1: Validation Process of the Task String Models.

6.2 THE FIRST-ROUND SURVEY

The purpose of the first-round survey is to eliminate a great number of discontinuous task strings to efficiently conduct the second-round survey. As a preparatory stage, the first-round survey was designed to evaluate those discontinuous task strings identified in the previous chapter five and to update the continuous task strings. To collect the information on the logic of the task strings, a survey questionnaire was used. Based on the results of the survey, it was determined whether or not the 362 hypothetically discontinuous task strings would be studied further in the-second round survey as continuous task strings. If they were confirmed as discontinuous task strings, the task strings were not included further in the study. Figure 6.2 shows an overview of the first-round survey.

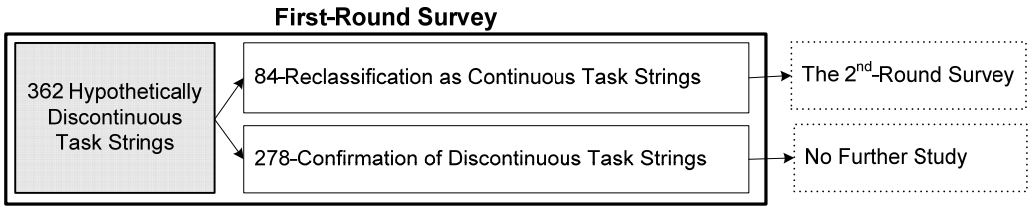

Figure 6.2: Validation Process of the First-Round Survey.

Questionnaire Development

Due to an excessive number of hypothetically discontinuous task strings, the questionnaire was broken down into four 15-minute segments. Each segment was comprised of 10 to13 closed questions which gave the respondent a choice of answers. This type of closed question is better suited for large-scale surveys because it is more easily analyzed and takes less time to answer. The questionnaire asked the same questions with different task strings. Therefore, four participants were required to

complete one questionnaire in the first-round survey. An example of the survey questionnaire is presented below in Figure 6.3. A complete set of the first-round survey questionnaires is presented in Appendix B.

The purpose of this study is to investigate task strings that pair pre-construction planning (PCP) tasks with project execution (PE) tasks for electrical contractors to achieve significantly better performance. In this survey, we are trying to identify tasks that you believe do or do not need to be performed during planning that set up the systems for managing the project following execution. During the survey, you are being asked to identify which pre-construction planning (PCP) tasks are needed to effectively implement the following project execution (PE) task. This opinion-based survey will take you about 15 minutes to complete. Please check the box in the left column if the PCP tasks need to be performed in order to effectively implement each of the PE task described below. If you think there are no PCP tasks that need to be completed in order to implement the PE task, check "None of the above".

---

* Required

1-1. PE Task 1: Setup office trailer in a timely manner and in a convenient location

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ Customize the computerized tracking & control system (database/schedule) for the current project
- ☐ None of the above

Figure 6.3: Example of the First-Round Survey Questionnaire.

Data Collection

In the first-round survey, each segment of the questionnaire was sent out to 45 electrical professionals in the U.S. through an email with a hyperlink to a survey form created using Google Docs. Four electrical professionals were required to assess a full set of the discontinuous task strings. As a result, a total of 28 responses were collected with a response rate of 62.2%: Segments I and II were responded to by five electrical professionals, while Segment III and IV were responded to by 7 electrical professionals. Therefore, five to seven sets of data were collected for the questionnaire regarding confirmation of hypothetically discontinuous task strings.

Survey Results

During the first-round survey, the participants were asked to assess which pre-construction planning (PCP) tasks, if any, are needed to effectively implement each specific project execution (PE) task. If any PCP tasks were selected by the majority of the participants, those tasks, including PE tasks, were reclassified and added to the continuous task strings for further analysis; otherwise, those confirmed discontinuous task strings were screened out and were not required for further study. As a result, of 362 hypothetically discontinuous task strings, 278 discontinuous task strings were confirmed, while 84 hypothetically discontinuous task strings were reclassified and added to the continuous task strings. Table 6.1 shows the 84 reclassified continuous task strings. The full list of the task strings with specific PCP and PE task descriptions are presented in Appendix C.

Task String		% of Selection by Experts	Task String		% of Selection by Experts	Task String		% of Selection by Experts
PCP#	PE#		PCP#	PE#		PCP#	PE#	
11	1	80	10	11	60	3	43	100
11	2	100	27	11	80	38	45	85.7
31	2	80	30	11	100	3	46	85.7
2	7	80	31	11	60	3	54	57.1
9	7	60	3	12	100	10	54	71.4
10	7	80	7	12	80	38	57	85.7
11	7	60	9	12	80	3	60	57.1
12	7	80	11	12	60	9	60	85.7
3	8	80	11	17	60	3	61	71.4
7	8	80	30	17	80	7	61	57.1
9	8	80	38	17	60	3	63	71.4
10	8	60	2	19	80	2	64	57.1
27	8	80	3	19	80	10	64	57.1
30	8	100	9	19	100	3	65	71.4
3	9	80	27	19	60	9	65	85.7
7	9	60	3	22	57.1	2	66	71.4
10	9	80	3	23	71.4	10	66	57.1
27	9	100	11	27	85.7	3	68	71.4
3	10	100	27	28	100	9	72	71.4
7	10	80	3	29	71.4	9	73	71.4
9	10	60	38	31	71.4	3	74	57.1
10	10	60	11	32	85.7	9	74	85.7
11	10	80	38	33	57.1	9	77	71.4
31	10	60	12	34	71.4	3	79	57.1
2	11	80	3	35	85.7	7	79	57.1
3	11	100	2	40	85.7	9	79	85.7
7	11	100	27	40	100	3	82	71.4
9	11	80	3	42	71.4	3	84	71.4

Table 6.1: Survey Results of the Reclassified Continuous Task Strings.

6.3 THE SECOND-ROUND SURVEY

The purpose of the second-round survey is to assess continuous task strings and their impact on cost and schedule success. The second-round survey included 155 hypothetically continuous task strings and 84 reclassified continuous task strings

developed in the previous chapters. As a result, a total of 239 continuous task strings were assessed by electrical professionals through a survey questionnaire. Due to the great number of task strings, the second-round survey questionnaire was also broken down into several segments. Figure 6.4 shows the process of the second-round survey.

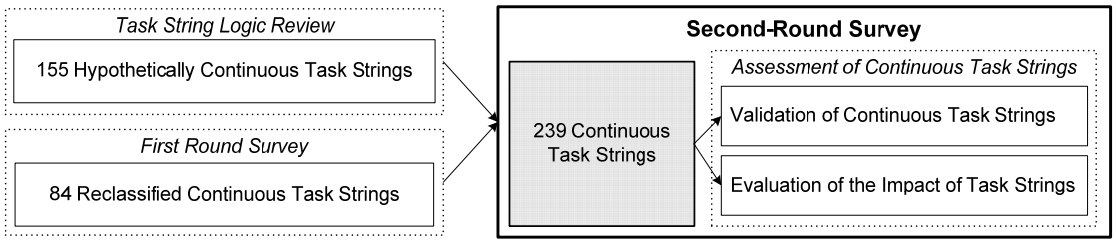

Figure 6.4: The Process of the Second-Round Survey.

Questionnaire Development

To collect information on the logic of the task strings and their impact on cost and schedule success, a survey questionnaire was developed using spreadsheets. Due to the large number of continuous task strings, the questionnaire was also broken down into five 15-minute segments so that electrical professionals could best complete the survey. Each segment was comprised of a series of continuous task strings that were assessed by the electrical professionals on a Likert scale of 0 to 4 (0=unimportant, 1=of little importance, 2=moderately important, 3=important, 4=very important). The specific questions are listed below:

(1) The importance of completing the PCP task in order to effectively implement the subsequent PE task;

(2) The importance of completing this task combination to achieve cost success; and

(3) The importance of completing this task combination to achieve schedule success.

These well-designed spreadsheets, including instructions, were distributed to electrical professionals in the United States through email. In the second survey, five participants were required to complete a full set of questionnaires. Figure 6.5 shows an example of the second-round survey questionnaire. A complete set of the second-round survey questionnaires is presented in Appendix D.

Q1. Please consider the following for PCP task #11: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	1	Setup office trailer in a timely manner and in a convenient location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	2	Setup storage trailer and lay down area in a convenient location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	7	Make sure the foreman has everything he or she needs to get started with the work	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	10	Implement an RFI tracking and processing system	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	31	Review the scope and document the subcontractors' scope of work	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	32	Implement subcontracts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	34	Request submittals and shop drawings from the subcontractors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	58	Identify work that impacts electrical activity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 6.5: Example of the Second-Round Questionnaire.

Data Collection

In the second-round survey, each segment of the questionnaire was sent out to 75 electrical professionals through an email with an attached spreadsheet. As a result, a total of 29 surveys were collected with a response rate of 38.7%. Segments I and II were responded to by six electrical professionals each, Segment III was responded to by seven electrical professionals, and Segments IV and V were responded to by five electrical professionals each. Therefore, five to seven sets of data were collected for the questionnaire regarding the evaluation of each group of continuous task strings.

Survey Results

During the second-round survey, the participants were solicited to assess the importance of the given PCP task to effectively implement the subsequent PE task on a 5-point Likert scale (0=unimportant, and 4=very important). Based on the results of the survey, the average value of the importance of the PCP task for successful PE task implementation was computed. To determine the cut off value of the importance, the average value of 1 (of little importance) was set. Therefore, if any PCP tasks were less than of little importance for successful PE tasks, those tasks, including PE tasks, were eliminated; otherwise, those hypothetical task string models were verified. As a result, all of the participants assessed the PCP task completion to be at least of little importance to effectively implement the succeeding PE tasks. This means that the hypothetically proposed continuous task strings represent logical relationships between PCP and PE tasks. Therefore, the hypothetically proposed 239 task strings were all verified as continuous task strings. Table 6.2 summarizes the results of the second-round survey for the 239 task strings between PCP and PE.

TS#	# of Responded Experts	Importance of PCP for PE	TS#	# of Responded Experts	Importance of PCP for PE	TS#	# of Responded Experts	Importance of PCP for PE
1	6	2.17	41	7	2.14	81	5	2.80
2	6	2.83	42	7	2.71	82	5	2.80
3	7	2.00	43	5	2.40	83	6	2.33
4	6	1.50	44	5	2.80	84	6	1.67
5	6	2.17	45	5	3.00	85	7	2.43
6	6	2.67	46	5	2.80	86	5	2.80
7	7	1.86	47	6	2.83	87	5	2.40
8	6	2.00	48	6	2.67	88	7	2.29
9	5	2.60	49	7	3.00	89	5	2.20
10	6	1.83	50	5	2.80	90	5	2.00
11	6	2.00	51	5	2.80	91	5	2.60
12	6	2.83	52	6	2.33	92	6	1.83
13	7	1.57	53	6	2.33	93	6	2.67
14	7	1.57	54	6	2.33	94	7	2.43
15	6	1.50	55	7	2.86	95	5	2.40
16	5	2.60	56	6	1.67	96	5	2.20
17	5	2.20	57	5	2.60	97	5	2.20
18	5	2.60	58	5	2.20	98	6	2.00
19	6	2.00	59	5	2.80	99	6	2.50
20	6	2.50	60	5	2.40	100	7	2.57
21	7	2.29	61	6	3.17	101	5	2.80
22	7	2.29	62	6	2.17	102	5	2.80
23	5	2.80	63	6	2.50	103	5	2.40
24	5	2.60	64	7	2.57	104	6	2.83
25	5	2.60	65	7	2.71	105	6	2.83
26	6	1.83	66	5	2.80	106	6	2.67
27	6	2.00	67	5	2.40	107	7	2.57
28	7	2.00	68	5	2.20	108	7	2.14
29	5	2.80	69	6	1.33	109	6	2.00
30	5	2.80	70	6	2.67	110	5	2.80
31	6	1.50	71	7	2.29	111	5	2.60
32	6	2.50	72	7	2.29	112	5	3.20
33	7	3.14	73	5	2.80	113	5	2.60
34	7	2.86	74	5	2.80	114	5	3.20
35	6	1.67	75	5	2.60	115	6	2.67
36	5	2.40	76	6	2.00	116	6	1.67
37	5	2.20	77	6	2.17	117	6	2.17
38	6	1.67	78	7	2.43	118	7	2.29
39	6	1.67	79	5	2.80	119	6	2.00
40	6	2.33	80	5	2.40	120	5	2.40

Table 6.2: Results of 239 Continuous Task Strings.

TS#	# of Responded Experts	Importance of PCP for PE	TS#	# of Responded Experts	Importance of PCP for PE	TS#	# of Responded Experts	Importance of PCP for PE
121	5	2.40	161	5	2.60	201	7	2.29
122	5	2.40	162	6	2.67	202	5	2.40
123	5	2.80	163	6	3.00	203	5	2.80
124	6	3.17	164	7	2.29	204	5	2.60
125	6	1.67	165	5	3.00	205	6	3.17
126	6	2.33	166	5	2.80	206	6	2.17
127	7	2.14	167	5	3.40	207	7	2.57
128	5	2.80	168	6	1.83	208	5	2.60
129	5	2.40	169	6	2.00	209	5	2.00
130	5	2.80	170	7	2.14	210	5	2.40
131	5	2.40	171	6	2.00	211	6	2.33
132	6	2.67	172	5	2.60	212	6	2.00
133	6	3.00	173	5	2.60	213	7	2.00
134	6	2.67	174	6	2.00	214	5	2.40
135	6	2.33	175	6	2.00	215	6	1.83
136	5	1.80	176	7	2.71	216	6	2.50
137	5	2.60	177	5	3.00	217	7	2.14
138	6	2.00	178	5	2.60	218	5	2.20
139	6	2.33	179	5	2.80	219	6	1.67
140	6	2.00	180	6	2.50	220	6	2.50
141	6	2.50	181	6	2.50	221	7	1.86
142	6	2.33	182	5	2.60	222	6	2.33
143	7	2.43	183	5	2.40	223	6	3.17
144	5	2.00	184	5	2.40	224	7	2.00
145	6	1.83	185	6	1.83	225	7	2.57
146	6	1.83	186	6	1.50	226	5	2.80
147	6	2.33	187	7	2.14	227	5	2.40
148	7	2.43	188	5	2.60	228	5	2.80
149	5	2.60	189	5	2.40	229	6	1.83
150	5	2.20	190	6	1.67	230	7	1.86
151	5	2.80	191	7	2.71	231	5	2.20
152	6	1.83	192	5	2.00	232	6	2.00
153	6	2.50	193	5	2.00	233	6	2.67
154	5	2.20	194	5	2.60	234	7	1.71
155	6	1.50	195	6	1.83	235	5	2.60
156	5	2.60	196	7	2.14	236	6	1.33
157	5	2.00	197	5	2.00	237	5	2.40
158	6	2.33	198	5	2.40	238	6	1.67
159	6	2.33	199	5	2.60	239	5	2.80
160	7	2.29	200	6	2.17			

Table 6.2: Results of 239 Continuous Task Strings (Continued).

6.4 SUMMARY OF THE CONTINUOUS TASK STRING MODELS

The continuous task string models were determined through a validation process in which each task string was reviewed by 5 to 7 electrical professionals. As a result, 239 task strings and their corresponding PCP and PE tasks were identified. A summary of the continuous task string models is provided below in Table 6.3. These validated task string models were further used to analyze the effects on cost and schedule success. The diagrams and of task strings in which PCP tasks were linked to relevant PE tasks are graphically summarized in Appendix E.

Task String Group	Total # of Continuous Task Strings	Related PCP Task #	Related PE Task #
Mobilization	18	2, 3, 7, 9, 10, 11,12, 30, 31	1, 2, 7
Document Management	33	2, 3, 7, 9, 10, 11, 27, 30, 38	8, 9, 10, 11, 12
Material Management	40	2, 3, 7, 9, 10, 12, 27, 30, 31, 38	17, 19, 22, 23, 25, 27
Tool Management	12	3, 7, 9, 10, 27, 30, 31, 38	28, 29
Subcontractor Management	37	2, 3, 7, 9, 10, 11, 12, 27, 30, 31, 38	31, 32, 33, 34, 35, 37
Safety Management	14	2, 3, 7, 9, 27, 30, 31	39, 40, 42
Communication	4	3, 38	43, 45, 46
Scope & Change Control	3	2, 10, 38	54
Scheduling	23	3, 7, 9, 10, 11, 30, 31, 38	57, 58, 60, 61
Cost Control & Billing	26	2, 3, 10, 12, 27, 38	63, 64, 65, 66, 68
Quality Management	11	3, 7, 9, 31	72, 73, 74
Labor Management	10	3, 7, 9, 10, 30, 31, 38	77, 78
Project Closeout	8	3, 7, 9, 38	79, 82, 84

Table 6.3: Summary of the Continuous Task String Models.

SECTION III: MODEL ANALYSIS

Chapter 7: Analyses of the Effects of Task Strings on Performance

7.1 Overview of the Analyses

This section discusses the research hypotheses and analysis procedures in order to identify the effects of task strings on project performance. To answer the second sets of research questions that were addressed in chapter 1.4, three research hypotheses were developed and analyzed. As part of the analysis, the continuous task string (TS) implementation score was also calculated. TS scores determine the degree to which contractors implemented task strings in electrical projects. As results of the analysis, two main effects of task strings on performance were investigated: (1) the effects of levels of task string usage on project performance, and (2) the leveraged effects of task strings on performance. Moreover, various statistical methods were also used with 50 electrical construction projects that were recently completed throughout the United States. These methods include a one-way ANOVA test, the Kruskal-Wallis test, the Mann-Whitney U test, an independent samples *t* test, and a logistic regression analysis. The effects of task string implementation were partially validated with a statistical data analysis.

7.2 Development of Hypotheses

The primary objective of this study was to investigate the effects of PCP-PE task strings on project performance. Three research hypotheses were developed to test (1) the impact of the levels of task string usage on project performance, (2) the leveraged impact of task strings as opposed to implementing either PCP or PE task individually, and (3) specific high-value task strings that have significantly greater impact. Table 7.1 summarizes three research questions and its corresponding hypothesis.

#	Research Question	Hypothesis
II-(a)	How does task string usage impact performance?	Levels of task string usage are positively associated with project success.
II-(b)	Does implementation of PCP/PE task strings leverage impact?	Implementation of task strings significantly improves the likelihood of achieving successful outcomes as opposed to implementing either the PCP or PE task individually.
III	Which specific PCP-PE task strings have potentially greater impact?	The impact of each PCP-PE task string on project performance varies based on the nature of task strings.

Table 7.1: Research Questions and Hypotheses.

7.3 TEST OF HYPOTHESES

To investigate the effects of task strings on performance, the three hypotheses were tested with different statistical methods. A continuous task string (TS) score was calculated to measure the levels of task string implementation in electrical projects. Using an independent samples *t* test, the relationship between task string implementation efforts and project success was identified. Furthermore, the leveraged effects of task strings were also investigated using the Kruskal-Wallis and the Mann-Whitney U tests. These tests determined whether the project success rates are significantly improved with task strings as opposed to implementing either PCP or PE task individually. To determine the ranking of task strings that have a greater impact on cost and schedule performance, a logistic regression analysis was conducted. Based on the results of the analyses, task strings ranked in basic/better/best task strings. The process of testing the research hypotheses is described in Figure 7.1.

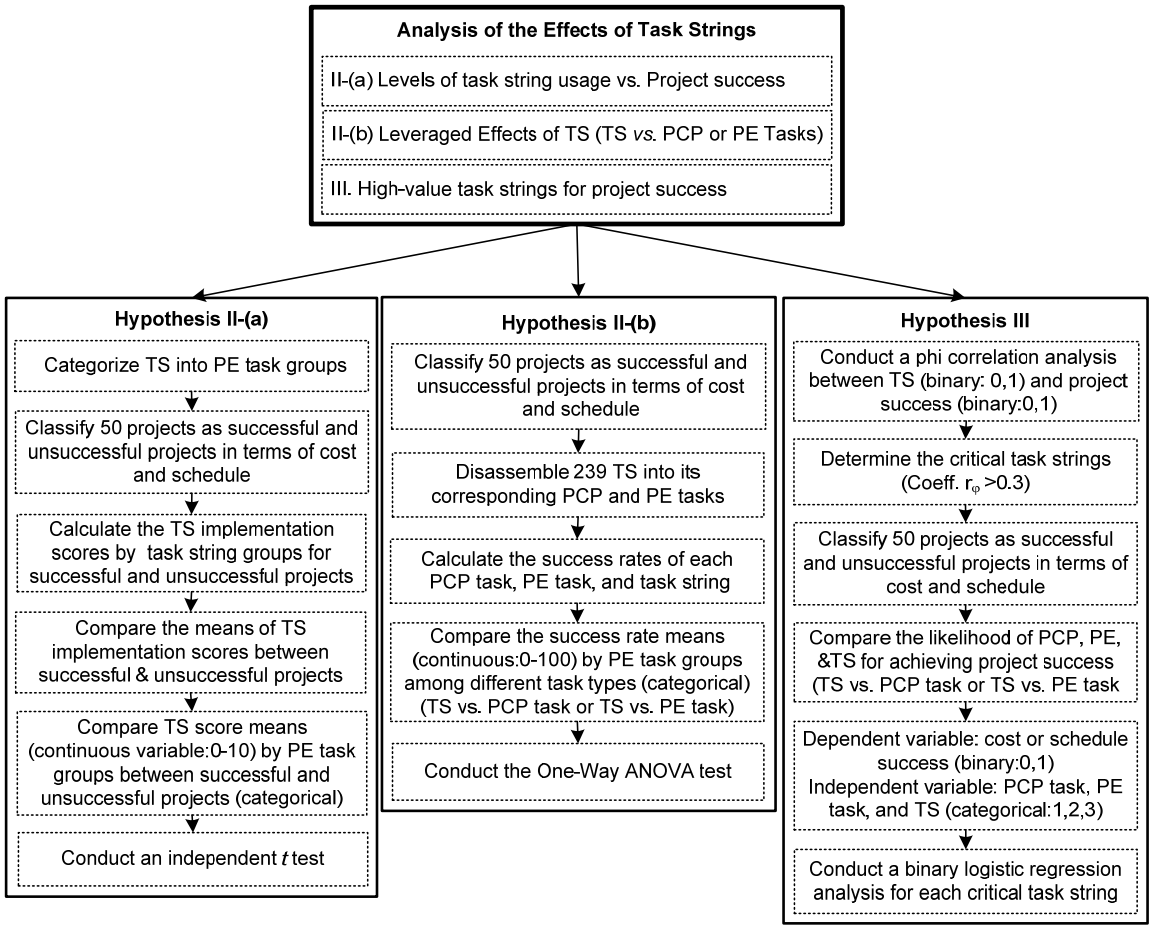

Figure 7.1: Process of Testing Three Research Hypotheses.

7.3.1 Test of Hypothesis II-(a)

The purpose of testing hypothesis II-(a) is to determine whether the levels of task string usage are positively related to project success. A continuous task string (TS) implementation score was calculated to measure the degree to which task strings were implemented in electrical projects. With the TS implementation scores, an independent samples *t* test was conducted to identify significant differences in task string usage

between successful projects and unsuccessful projects. The specific steps for testing are summarized below:

Step 1: Categorize task strings into PE task groups

Step 2: Classify 50 projects as successful and unsuccessful projects in terms of cost and schedule performance

Step 3: Calculate each TS implementation score for 50 electrical projects.

Step 4: Compare the TS implementation score means for successful projects to unsuccessful projects.

Step 5: Conduct an independent samples *t* test to identify whether levels of task string implementation are positively associated with cost and schedule success.

Step 6: Test hypothesis II-(a) and summarize the results.

To measure the levels of task string implementation efforts in 50 sampled projects, task string (TS) implementation scores were calculated with or without consideration of its relative importance. The relative importance of each task string was computed with the averaged scores of the importance of the task string on cost and schedule success from the survey results.

Using an independent samples *t* test, these TS implementation scores by PCP task-to-PE group were compared to determine whether there is a significant difference in task string usage between successful projects and unsuccessful projects. This analysis consequently compared the TS mean scores of successful projects and unsuccessful projects. Finally, hypothesis II-(a) was tested and the results were summarized.

7.3.2 Test of Hypothesis II-(b)

The leveraged effects of task strings on project performance were investigated to identify whether project performance can be improved by implementing task strings as opposed to either implementing PCP or PE task individually. The analysis employed a probabilistic approach that uses the likelihood of achieving successful outcomes in 50 electrical construction projects. To test hypothesis II-(b), the following steps were taken:

Step 1: Classify projects into successful and unsuccessful outcomes in terms of cost and schedule.

Step 2: Disassemble the task strings into three task types: (1) PCP task; (2) PE task; and (3) PCP-PE task string.

Step 3: Calculate the likelihood of each PCP task, PE task, and task string achieving a successful outcome.

Step 4: Conduct the one-way ANOVA test to compare the means of project success rates among the different task types.

Step 5: Test hypothesis II-(b) and summarize the results.

Firstly, projects were classified into successful and unsuccessful outcomes in terms of cost and schedule. A successful project is basically defined as a project that achieved planned outcomes; otherwise, it is called an unsuccessful project. To transform values of project performance into binary values, 0 and 1 (0=unsuccessful and 1=successful) were used. As a result, of the 50 electrical construction projects 30 were classified as successful in cost and 42 in schedule.

Secondly, the task strings were disassembled into three task types: (1) PCP task, (2) PE task, and (3) PCP-PE task string. Thirdly, the likelihood of each PCP task, PE task, and task string achieving a successful outcome was calculated with the validated PCP-PE task strings. Among 46 PCP tasks and 85 PE tasks, only those tasks included in the continuous task strings were considered for the analysis. This probabilistic approach entirely depends on the frequency of each task implementation. The basic idea of calculating the probability is to place the number of task implementations for successful projects over the total number of task implementations for all projects. Equations 7.1-3 show the mathematical expressions used to calculate the probability of achieving successful outcomes.

$$\text{Success rate of task string} = \frac{\text{Frequency of task string in successful projects}}{\text{Frequency of task string in overall projects}} \tag{7.1}$$

$$\text{Success rate of PCP task} = \frac{\text{Frequency of (PCP task} - \text{task string) in successful projects}}{\text{Frequency of (PCP task} - \text{task string) in overall projects}} \tag{7.2}$$

$$\text{Success rate of PE task} = \frac{\text{Frequency of (PE task} - \text{task string) in successful projects}}{\text{Frequency of (PE task} - \text{task string) in overall projects}} \tag{7.3}$$

Based on the equations 7.1-3, the success rates of 239 PCP-PE task strings and their corresponding individual PCP and PE tasks were calculated. The following example helps to explain the probability computation process: Let's assume that 30 out of 50 total construction projects achieved successful project performance. Among the 30 successful projects, a PCP task #5 was performed 8 times, a PE task #15 was performed 13 times, and both of the two tasks that are believed to be continuously implemented for effective PM were performed 10 times. In 20 unsuccessful projects, however, the PCP task was

performed 12 times, the PE task was performed 12 times, and the continuous task string was performed 5 times. Figure 6.2 graphically summarizes this example.

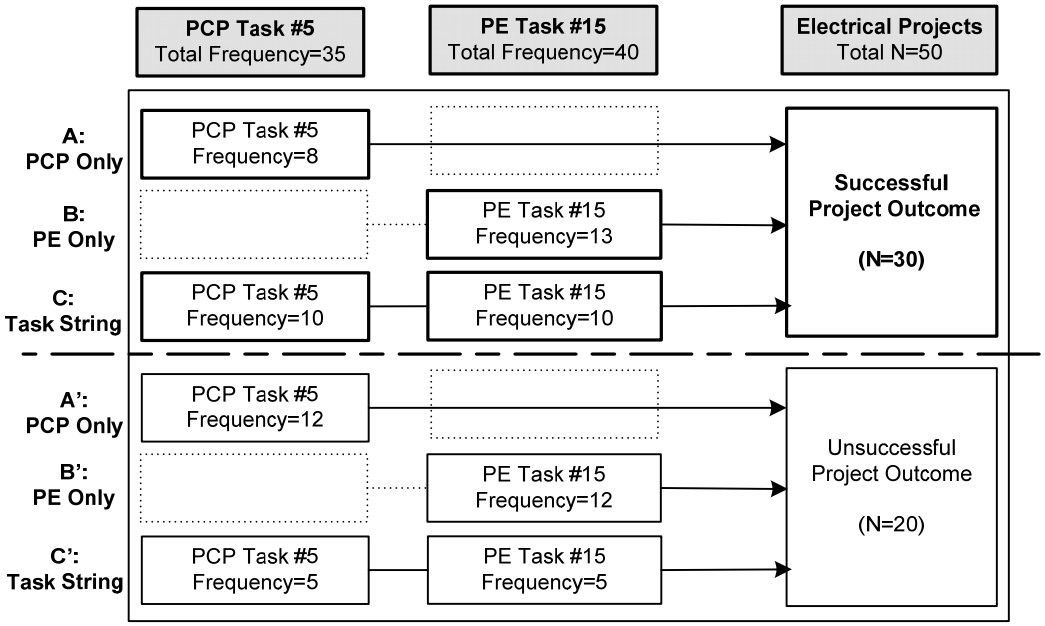

Figure 7.2: Example of the Probability Computation Process

Based on the equations 7.1-3, the probability of each task for achieving successful cost performance is calculated below:

- Success rate of task string = C/(C+C') =10/(10+5) = 10/15 = 0.667 → 66.7%
- Success rate of PCP #5 = A/(A+A') =8/20 = 0.4 → 40.0%
- Success rate of PE #15 = B/(B+B') = 13/25 = 0.52 → 52.0%

Fourthly, the one-way ANOVA test was conducted to identify whether the effect of the continuous task string is more significant than that of the PCP or PE task alone. Then, hypothesis II-(b) was finally tested based on the results of the analysis.

7.3.3 Test of Hypothesis III

The purpose of testing hypothesis III is to identify the high-value task strings that have potentially greater impact on performance. These high-value task strings were defined as task strings that have significantly positive association with project outcomes and at the same time have a significantly leveraged effect on project success compared to implementing either PCP or PE task individually. These strings ranked in basic/better/best task strings based on the results of the leveraged effects of using task strings as opposed to implementing either PCP or PE task individually. To identify the high-value task strings, two statistical analyses were conducted, including a correlation analysis and a logistic regression analysis. The specific steps for testing hypothesis three are summarized below:

Step 1: Conduct a phi correlation analysis between each task string and cost and schedule success.

Step 2: Determine the task strings that are positively correlated with cost and schedule success.

Step 3: Conduct a logistic regression analysis to identify the leveraged effects of task strings on project performance.

Step 4: Identify the added value of the task string compared to implementing either PCP or PE task individually.

Step 5: Summarize the basic/better/best task strings based on the results of the leveraged effects.

Step 6: Test hypothesis III and summarize the results.

To measure the degree of association between task strings and project outcomes, a correlation analysis was conducted. The correlation coefficient determines the strength of the relationship between two variables. Based on the result of the correlation analysis, those task strings whose p-values are smaller than 0.05 and whose coefficients indicated positive association were selected for the high-value task strings.

In addition, these task strings were further analyzed to identify how much value was added compared to individual implementation of PCP or PE task. A logistic regression analysis was conducted for each task string. This analysis used binary values (presence or absence) of the task string, and its corresponding PCP and PE tasks, including cost and schedule success. The result of the analysis provided chi-square statistic and the odd ratios for the predictors with exponentiation of the coefficients. Consequently, the analysis identified whether the task strings have leveraged effects and how much value they add as opposed to implementing either PCP or PE task individually. Based on the results of the leveraged effects, the task strings further ranked in basic/better/best task strings. Then, hypothesis III was finally tested and the list of task strings that have potentially greater effects on cost and schedule success was summarized.

7.4 Summary of the Analysis of Task Strings

This chapter described the specific analysis procedures used to investigate the effects of task strings on project performance. For the purpose of the analysis, three hypotheses were developed in accordance with the research questions. To test the hypotheses, various statistical methods were used. These analyses identified two main effects of task strings on project performance by categorizing task strings into PCP task-

to-PE group: correlation between task strings and project success, and leveraged effects of task strings on project success as opposed to implementing either PCP or PE task individually. Almost the same effects were also investigated for specific task strings to identify the high-value task strings that have greater effects on project performance using a correlation analysis and a logistic regression analysis. Based on the results of the analyses 239 continuous task strings ranked in basic/better/best task strings.

Chapter 8: Task String Usage and Project Success Correlation

8.1 Introduction

The purpose of this study was to identify whether project success is impacted by task string implementation. To quantify the effort of task string implementation, the task string score was calculated. In computing the TS implementation score, uniform weights were initially applied to each task string for sake of simplicity. However, subsequent analyses adopted non-uniform weights that represent the relative importance of each task string. To determine the weight values of task strings, 29 electrical professionals assessed their importance to cost and schedule success, as discussed previously in Chapter 6. With the weighted and unweighted task strings, the level of task string implementation was measured for electrical projects. Based on this quantification, the study investigated the effect of task string usage on project cost and schedule success.

8.2 Measurement of Task String Implementation

A task string (TS) implementation score measures the level of task string implementation in electrical projects. The task strings were classified into 13 PCP task-to-PE groups based on the project execution task category. These task string groups include mobilization, document management, material management, tool management, subcontractor management, safety management, communication, scope change and control, scheduling, cost control and billing, quality management, labor management, and project closeout. Thus, the TS implementation scores quantified the degree to which task strings were implemented within the PCP task-to-PE group during the two phases: pre-construction planning and project execution. For the purpose of simplicity, uniform

weights were initially applied to task strings in order not to bias results. The formula for TS implementation score is computed as shown in below:

$$\text{TS Implementation Score} = \sum_{i=1}^{k} (\text{TS}_i)/\text{N} \tag{8.1}$$

where, TS_i=task string implementation, N=number of task strings in the PCP task-to-PE group.

In the subsequent analysis, the weight of each task string was also applied to reflect its relative importance. To determine the weights of task strings, the survey results from the validation process in Chapter 6 were used. Five to seven electrical professionals assessed the importance of each task string for achieving cost and schedule success on the Likert scale of 0 to 4 (0=unimportant, 4=very important). The results of the experts' assessment are summarized below in Table 8.1. To make the relative importance more understandable, the raw score of the assessment was converted to a 0–10 score by multiplying by 2.5. These converted average scores of the importance on cost and schedule were used as weight values of task strings. The formula for TS implementation score is computed as shown in below:

$$\text{TS Implementation Score} = \sum_{i=1}^{k} (\text{TS}_i\text{W}_i \times 2.5)/\text{N} \tag{8.2}$$

where, TS_i=task string implementation, W_i=relative importance of task string, N=number of task strings in the PCP task-to-PE group.

TS #	# of experts	Average Score		TS #	# of experts	Average Score		TS #	# of experts	Average Score	
		Cost impact	Schedule impact			Cost impact	Schedule impact			Cost impact	Schedule impact
1	6	2.33	2.33	41	7	2.00	2.29	81	5	2.80	2.20
2	6	2.67	3.00	42	7	2.29	2.57	82	5	2.40	2.60
3	7	1.57	1.86	43	5	1.60	2.20	83	6	2.83	2.50
4	6	1.67	1.83	44	5	2.20	2.40	84	6	1.50	1.50
5	6	2.33	2.33	45	5	3.00	2.80	85	7	2.57	2.29
6	6	2.67	2.67	46	5	2.60	2.60	86	5	2.60	2.40
7	7	1.86	1.86	47	5	2.50	2.83	87	5	3.00	3.00
8	6	1.83	2.00	48	5	2.67	2.83	88	7	2.57	2.29
9	5	2.20	2.80	49	5	2.86	3.14	89	5	2.40	1.60
10	6	2.17	2.33	50	5	2.60	3.00	90	5	2.20	2.60
11	6	1.67	2.33	51	5	2.60	2.60	91	5	2.20	2.60
12	6	1.83	3.17	52	5	2.17	2.50	92	6	1.50	2.00
13	7	1.71	1.86	53	5	1.67	2.00	93	6	2.50	2.83
14	7	1.57	1.43	54	5	2.33	2.33	94	7	2.43	2.14
15	6	1.33	1.50	55	5	2.57	2.71	95	5	2.60	2.80
16	5	2.40	3.00	56	5	1.83	2.00	96	5	2.40	2.40
17	5	2.60	2.40	57	5	2.80	2.80	97	5	2.20	2.60
18	5	2.60	2.40	58	5	2.20	2.20	98	6	2.17	2.67
19	6	1.67	1.83	59	5	2.60	2.00	99	6	2.17	2.83
20	6	2.00	2.33	60	5	2.20	2.40	100	7	2.57	2.71
21	7	2.29	2.14	61	5	2.17	3.50	101	5	2.60	3.00
22	7	2.14	2.14	62	5	1.67	2.33	102	5	2.80	2.20
23	5	2.20	2.60	63	5	2.33	3.00	103	5	2.20	2.40
24	5	2.20	2.60	64	5	2.43	2.86	104	6	2.83	3.00
25	5	2.20	2.60	65	5	2.57	2.71	105	6	2.00	2.33
26	6	1.83	2.00	66	5	2.40	2.60	106	6	2.00	2.67
27	6	2.00	2.83	67	5	2.40	2.20	107	7	2.71	2.29
28	7	2.00	2.14	68	5	1.80	1.80	108	7	2.29	2.00
29	5	1.60	2.20	69	5	1.50	2.17	109	6	2.00	2.17
30	5	2.40	2.60	70	5	2.00	3.00	110	5	2.60	2.40
31	6	1.17	1.67	71	5	2.14	2.29	111	5	2.60	2.80
32	6	2.33	2.83	72	5	2.43	2.71	112	5	3.00	3.20
33	7	3.00	3.14	73	5	2.60	2.80	113	5	2.40	2.40
34	7	2.57	2.86	74	5	2.80	2.40	114	5	3.20	3.00
35	6	1.83	1.83	75	5	2.20	2.40	115	6	2.33	3.17
36	5	2.40	2.00	76	5	1.33	2.17	116	6	2.17	2.33
37	5	2.20	2.00	77	5	2.00	2.83	117	6	2.17	2.33
38	6	2.33	2.33	78	5	2.43	2.71	118	7	2.43	2.29
39	6	1.83	1.50	79	5	2.80	2.20	119	6	2.17	2.17
40	6	3.00	2.83	80	5	2.20	2.80	120	5	2.20	2.00

Table 8.1: Assessment of the Importance of the Task Strings.

TS #	# of experts	Average Score		TS #	# of experts	Average Score		TS #	# of experts	Average Score	
		Cost Impact	Schedule Impact			Cost Impact	Schedule Impact			Cost Impact	Schedule Impact
121	5	2.40	2.40	161	5	2.60	2.60	201	7	2.29	2.29
122	5	2.40	2.60	162	6	2.67	2.83	202	5	2.00	2.00
123	5	2.60	2.60	163	6	2.17	2.67	203	5	3.00	2.80
124	6	2.17	3.17	164	7	2.14	2.43	204	5	2.00	2.80
125	6	1.83	2.17	165	5	3.00	2.80	205	6	2.83	2.50
126	6	2.00	3.00	166	5	3.00	2.60	206	6	2.00	1.33
127	7	2.00	2.14	167	5	3.20	3.40	207	7	2.43	2.14
128	5	2.20	2.40	168	6	1.83	2.17	208	5	2.20	2.40
129	5	2.00	2.60	169	6	2.17	2.50	209	5	2.80	2.20
130	5	2.80	2.60	170	7	2.00	2.14	210	5	2.20	2.60
131	5	2.40	2.40	171	6	2.17	2.33	211	6	1.50	1.33
132	6	2.00	3.00	172	5	2.60	2.40	212	6	1.83	2.33
133	6	2.00	2.33	173	5	3.00	2.40	213	7	2.14	1.86
134	6	1.83	2.33	174	6	1.83	2.17	214	5	2.80	2.20
135	6	2.33	2.50	175	6	2.00	2.67	215	6	1.83	2.17
136	5	2.20	2.80	176	7	2.29	2.86	216	6	2.33	2.33
137	5	2.60	2.60	177	5	2.60	2.60	217	7	2.14	2.14
138	6	1.83	2.33	178	5	2.60	2.40	218	5	2.20	2.20
139	6	1.67	2.67	179	5	2.60	2.80	219	6	1.67	2.00
140	6	1.83	2.17	180	6	1.67	2.33	220	6	2.00	2.50
141	6	2.50	2.33	181	6	2.00	2.83	221	7	1.86	2.00
142	6	2.00	1.67	182	5	2.80	2.60	222	6	2.00	2.50
143	7	2.14	2.14	183	5	2.60	2.20	223	6	2.67	2.50
144	5	2.40	2.20	184	5	2.20	2.60	224	7	2.29	2.14
145	6	1.67	1.83	185	6	2.33	2.17	225	7	2.43	2.43
146	6	2.17	2.00	186	6	1.33	1.33	226	5	2.80	2.60
147	6	2.17	1.83	187	7	2.14	2.00	227	5	2.20	2.40
148	7	2.14	2.29	188	5	2.00	1.80	228	5	2.40	2.80
149	5	2.60	2.80	189	5	1.80	2.00	229	6	2.00	2.00
150	5	2.00	2.20	190	6	2.50	1.67	230	7	2.14	2.14
151	5	2.60	2.60	191	7	2.43	2.00	231	5	2.20	2.60
152	6	2.17	2.17	192	5	2.40	1.80	232	6	1.83	1.67
153	6	2.33	2.17	193	5	2.20	1.80	233	6	2.00	2.83
154	5	2.80	2.60	194	5	2.20	2.80	234	7	1.86	1.86
155	6	1.33	1.83	195	6	1.67	1.50	235	5	2.60	2.60
156	5	2.60	2.60	196	7	2.71	2.00	236	6	1.83	1.83
157	5	2.00	2.00	197	5	2.40	1.80	237	5	2.20	2.40
158	6	2.33	1.83	198	5	3.00	2.80	238	6	1.67	1.50
159	6	2.67	2.17	199	5	2.20	2.60	239	5	2.60	2.80
160	7	1.86	2.14	200	6	2.50	2.33				

Table 8.1: Assessment of the Importance of the Task Strings (Continued).

8.3 TEST OF HYPOTHESIS II-(A)

The main purpose of this study was to investigate the effects of task strings on project success in terms of cost and schedule performance. An independent samples *t* test was conducted to determine whether there is a significant difference in task string usage between successful projects and unsuccessful projects. To conduct an independent samples *t* test, the dependent variable must be measured on an interval or ratio scale. In addition, three assumptions should be met, including normality, independence, and equal variance. An inferential statistic, Levene's test, was also used to assess the equality of variances of the population. In the analysis, the null hypothesis was tested at the significance level of 0.05. Thus, if the p value is greater than 0.05, the null hypothesis is accepted; otherwise, the alternative hypothesis is accepted. The null and alternative hypotheses are described below:

- H_0: The TS implementation score means are equal between successful projects and unsuccessful projects.
- H_1: The TS implementation score means of the two independent groups are not equal.

8.4 ANALYSIS RESULTS FOR COST SUCCESS

The focus of the cost success analysis was to determine if there is a statistically significant difference between projects with cost success and failure in task string implementation. Of the 50 electrical projects 30 were classified as successful in cost and 20 as unsuccessful. For the purpose of the analysis, the task strings were broken down into 13 PCP task-to-PE groups based on the PE task categories. As a result, the TS

implementation score mean of successful projects was compared to that of unsuccessful projects within the PCP task-to-PE group.

8.4.1 The Impact of Unweighted Task Strings on Cost Success

The TS implementation scores were computed with the unweighted task strings in terms of successful and unsuccessful projects in cost. The mean score can range from 0 to 1. For example, the mean value of 1 indicates that all of the task strings within each PCP task-to-PE group were implemented for successful or unsuccessful projects; while, the mean value of 0 indicates that none of the task strings were implemented. The TS implementation score means of the successful and unsuccessful projects in cost are graphically presented in Figure 8.1.

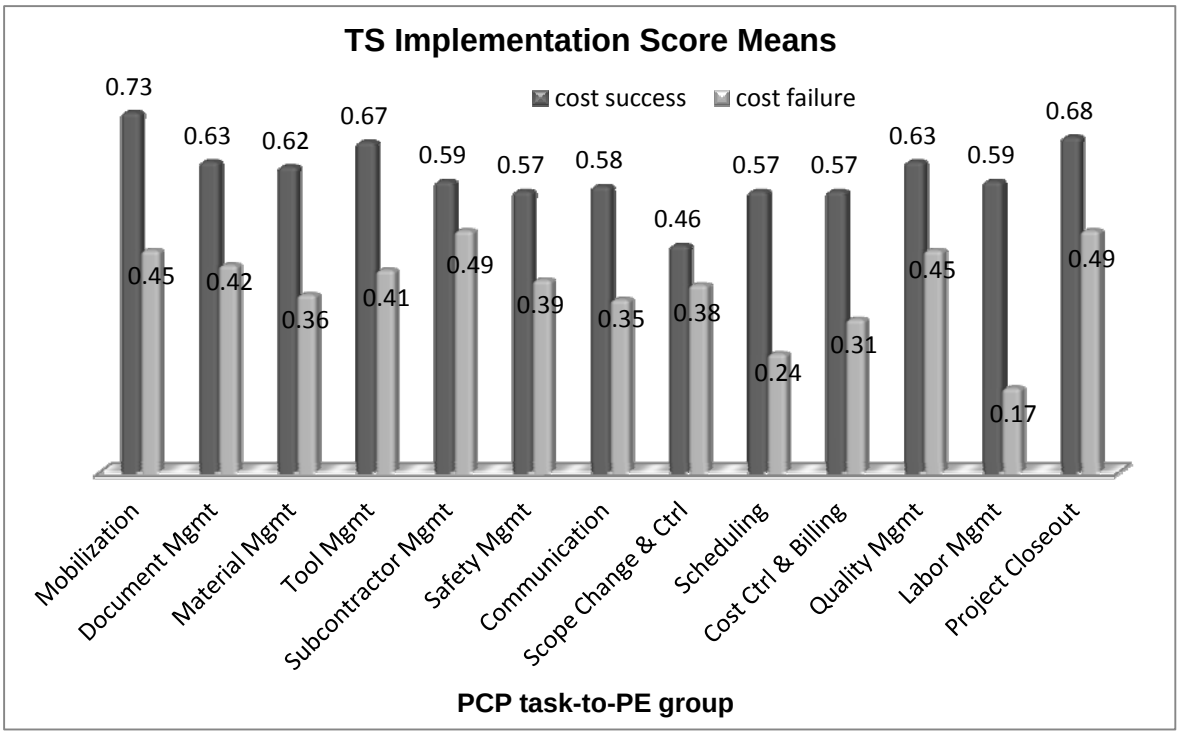

Figure 8.1: Unweighted Task String Implementation Score Mean for Cost.

An independent samples *t* test was conducted to investigate the difference in task string usage. The results indicated that most of the PCP task-to-PE groups are significantly different between successful and unsuccessful projects at the 95% confidence level. Thus, with the exception of subcontractor management, safety management, and scope change and control, task string groups may contribute significantly to cost success. In particular, these groups include mobilization, document management, tool management, communication, scheduling, cost control and billing, quality management, labor management, and project closeout. However, other task string groups did not produce statistically significant results. Table 8.2 shows the results of the independent samples *t* tests for cost performance.

		Projects with Cost Success			*Projects with Cost Failure*						
#	PCP Task-to-PE Group	N	M	SD	N	M	SD	Mean difference	*t* statistic	Sig. (two-tailed)	Eta square
1	Mobilization	30	0.73	0.04	20	0.45	0.06	0.28	4.23	0.000	0.272
2	Document Mgmt	30	0.63	0.26	20	0.42	0.27	0.21	2.81	0.007	0.141
3	Material Mgmt	30	0.62	0.24	20	0.36	0.24	0.26	3.73	0.001	0.225
4	Tool Mgmt	30	0.67	0.28	20	0.41	0.33	0.26	2.92	0.005	0.151
5	Subcontractor Mgmt	30	0.59	0.29	20	0.49	0.34	0.10	–	–	–
6	Safety Mgmt	30	0.57	0.37	20	0.39	0.36	0.18	–	–	–
7	Communication	30	0.58	0.32	20	0.35	0.34	0.23	2.45	0.018	0.111
8	Scope Change & Ctrl	30	0.46	0.37	20	0.38	0.39	0.08	–	–	–
9	Scheduling	30	0.57	0.36	20	0.24	0.28	0.33	3.44	0.001	0.198
10	Cost Ctrl & Billing	30	0.57	0.23	20	0.31	0.26	0.26	3.78	0.000	0.229
11	Quality Mgmt	30	0.63	0.29	20	0.45	0.33	0.18	2.05	0.046	0.081
12	Labor Mgmt	30	0.59	0.32	20	0.17	0.27	0.42	4.88	0.000	0.332
13	Project Closeout	30	0.68	0.27	20	0.49	0.30	0.19	2.39	0.021	0.106

Table 8.2: The Effect of Unweighted Task String Usage on Cost Success.

8.4.2 The Impact of Weighted Task Strings on Cost Success

The TS implementation scores were subsequently computed with the weighted task strings in terms of successful and unsuccessful projects. The mean score can range from 0 to 10. The TS implementation score means of successful and unsuccessful projects are graphically presented in Figure 8.2.

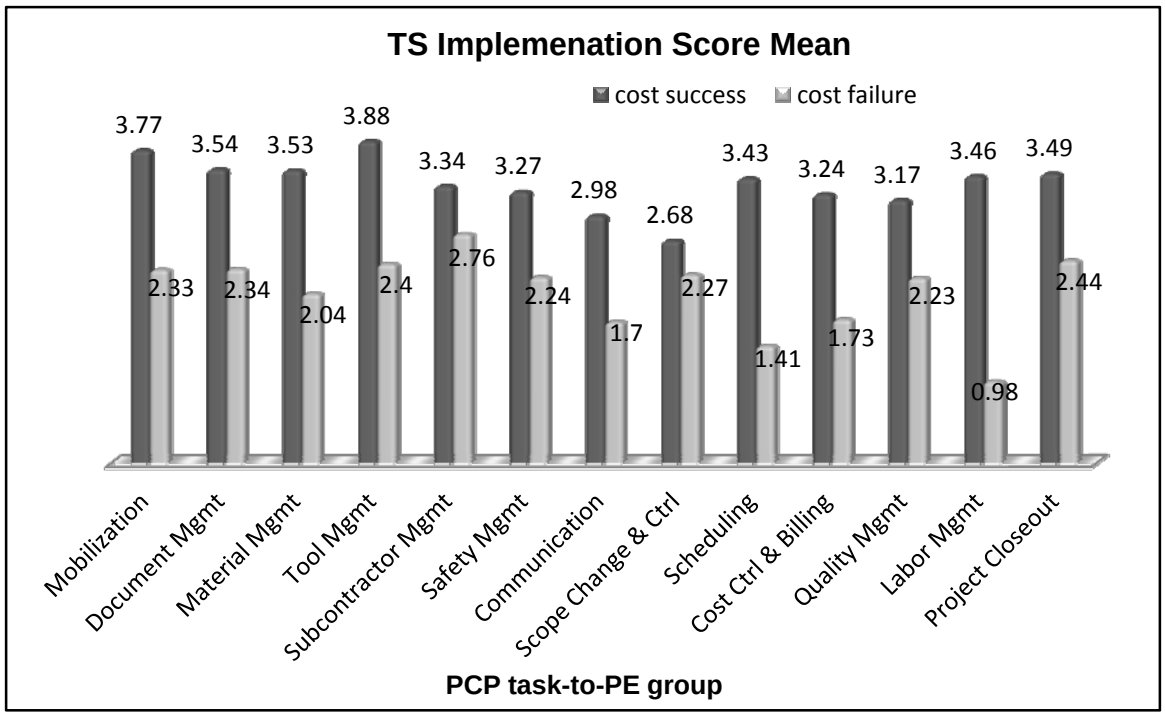

Figure 8.2: Weighted Task String Implementation Score Mean for Cost.

Like the unweighted task string analysis, an independent samples *t* test was also conducted to investigate the difference in task string usage. The results indicated that most of the task string groups are significantly different between successful and unsuccessful projects at the 95% confidence level. These results consistently matched with those of unweighted task string analysis. Specifically, these task string groups include mobilization, document management, tool management, communication,

scheduling, cost control and billing, quality management, labor management, and project closeout. However, other task string groups did not produce statistically significant results. Table 8.3 shows the results of the independent samples *t* tests for cost performance.

		Projects with Cost Success			*Projects with Cost Failure*						
#	PCP Task-to-PE Group	N	M	SD	N	M	SD	Mean difference	*t* statistic	Sig. (two-tailed)	Eta square
1	Mobilization	30	3.77	1.10	20	2.33	1.32	1.43	4.18	0.000	0.266
2	Document Mgmt	30	3.54	1.45	20	2.34	1.49	1.20	2.84	0.007	0.144
3	Material Mgmt	30	3.53	1.39	20	2.04	1.38	1.49	3.74	0.000	0.226
4	Tool Mgmt	30	3.88	1.68	20	2.40	1.92	1.48	2.89	0.006	0.148
5	Subcontractor Mgmt	30	3.34	1.65	20	2.76	1.94	0.58	–	–	–
6	Safety Mgmt	30	3.27	2.12	20	2.24	2.06	1.03	–	–	–
7	Communication	30	2.98	1.68	20	1.70	1.77	1.28	2.58	0.013	0.122
8	Scope Change & Ctrl	30	2.68	2.19	20	2.27	2.35	0.41	–	–	–
9	Scheduling	30	3.43	2.15	20	1.41	1.68	2.02	3.54	0.001	0.207
10	Cost Ctrl & Billing	30	3.24	1.33	20	1.73	1.47	1.51	3.78	0.000	0.229
11	Quality Mgmt	30	3.17	1.49	20	2.23	1.66	0.94	2.10	0.041	0.084
12	Labor Mgmt	30	3.46	1.85	20	0.98	1.59	2.48	4.92	0.000	0.335
13	Project Closeout	30	3.49	1.48	20	2.44	1.56	1.05	2.40	0.020	0.107

Table 8.3: The Effect of Weighted Task String Usage on Cost Success.

8.5 ANALYSIS RESULTS FOR SCHEDULE SUCCESS

The schedule success analysis focused on determining if there is a statistically significant difference between projects with schedule success and failure in task string usage. Of the 50 electrical construction projects 42 were classified as successful and 8 as unsuccessful in schedule. For the purpose of the analysis, the TS implementation score

mean of successful projects was compared to that of unsuccessful projects within each task string group.

8.5.1 The Impact of Unweighted Task Strings on Schedule Success

The TS implementation scores were computed with the unweighted task strings in terms of successful and unsuccessful projects in schedule. The mean score can range from 0 to 1. For example, the mean value of 1 indicates that all of the task strings within each task string group were implemented for successful or unsuccessful projects; while, the mean value of 0 indicates that none of the task strings were implemented. The TS implementation score means of the successful and unsuccessful projects in schedule are graphically presented in Figure 8.3.

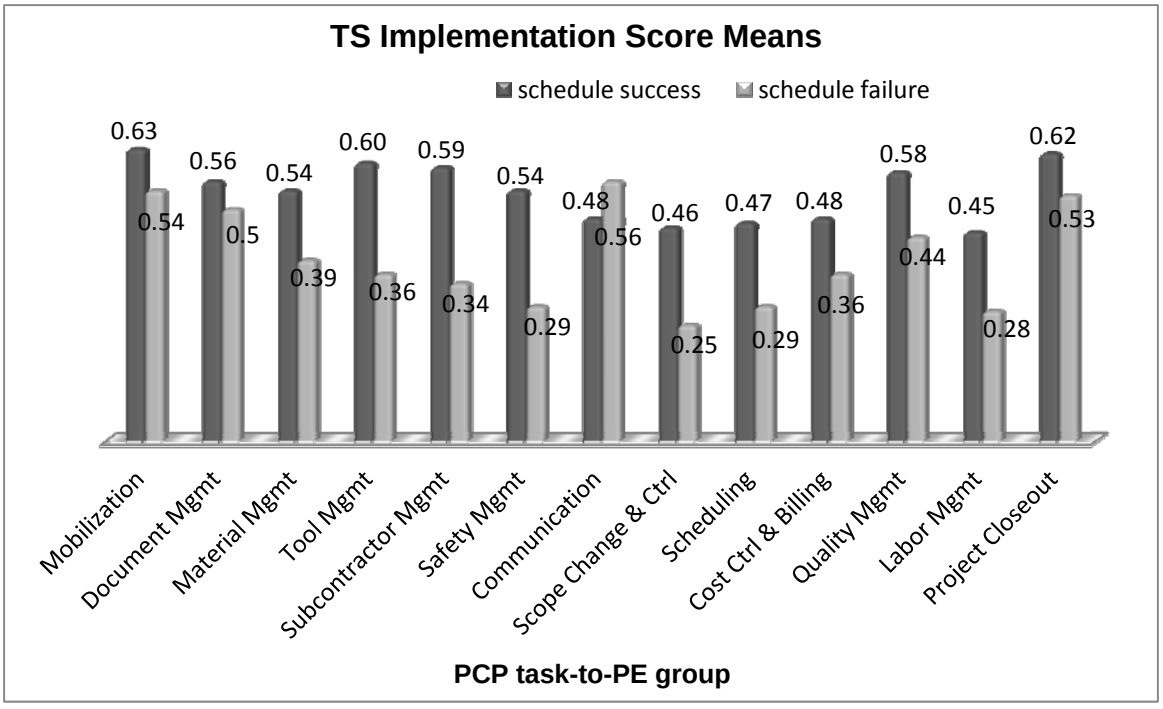

Figure 8.3: Unweighted Task String Implementation Score Mean for Schedule.

An independent samples *t* test was conducted to investigate the difference in task string usage. The results indicated that the impact of using task strings within the subcontractor management group is significantly different between successful and unsuccessful projects at the 95% confidence level. The results indicated that three task string groups–tool management, subcontractor management, and safety management–may contribute significantly to schedule success. Although tool management and safety management groups showed a significant difference between successful and unsuccessful projects at the 90% confidence level, other task string groups did not produce statistically significant results. These groups include mobilization, document management, material management, scope change and control, scheduling, cost control and billing, quality management, labor management, and project closeout. Table 8.4 describes the results of the independent samples *t* tests for schedule performance.

		Projects with Schedule Success			Projects with Schedule Failure						
#	PCP Task-to-PE Group	N	M	SD	N	M	SD	Mean difference	*t* statistic	Sig. (two-tailed)	Eta square
1	Mobilization	42	0.63	0.27	8	0.54	0.23	0.09	–	–	–
2	Document Mgmt	42	0.56	0.29	8	0.50	0.24	0.06	–	–	–
3	Material Mgmt	42	0.54	0.27	8	0.39	0.22	0.15	–	–	–
4	Tool Mgmt	42	0.60	0.32	8	0.36	0.28	0.24	1.96	0.055	0.074
5	Subcontractor Mgmt	42	0.59	0.29	8	0.34	0.34	0.25	2.16	0.036	0.089
6	Safety Mgmt	42	0.54	0.37	8	0.29	0.35	0.26	1.81	0.076	0.064
7	Communication	42	0.48	0.35	8	0.56	0.35	-0.09	–	–	–
8	Scope Change & Ctrl	42	0.46	0.37	8	0.25	0.39	0.21	–	–	–
9	Scheduling	42	0.47	0.38	8	0.29	0.27	0.18	–	–	–
10	Cost Ctrl & Billing	42	0.48	0.27	8	0.36	0.26	0.12	–	–	–
11	Quality Mgmt	42	0.58	0.32	8	0.44	0.30	0.14	–	–	–
12	Labor Mgmt	42	0.45	0.37	8	0.28	0.32	0.18	–	–	–
13	Project Closeout	42	0.62	0.29	8	0.53	0.35	0.09	–	–	–

Table 8.4: The Effect of Unweighted Task String Usage on Schedule Success.

8.5.2 The impact of Weighted Task Strings on Schedule Success

The TS implementation scores were subsequently computed with the weighted task strings in terms of successful and unsuccessful projects in schedule. The mean score can range from 0 to 10. The TS implementation score means of successful and unsuccessful projects are graphically presented in Figure 8.4.

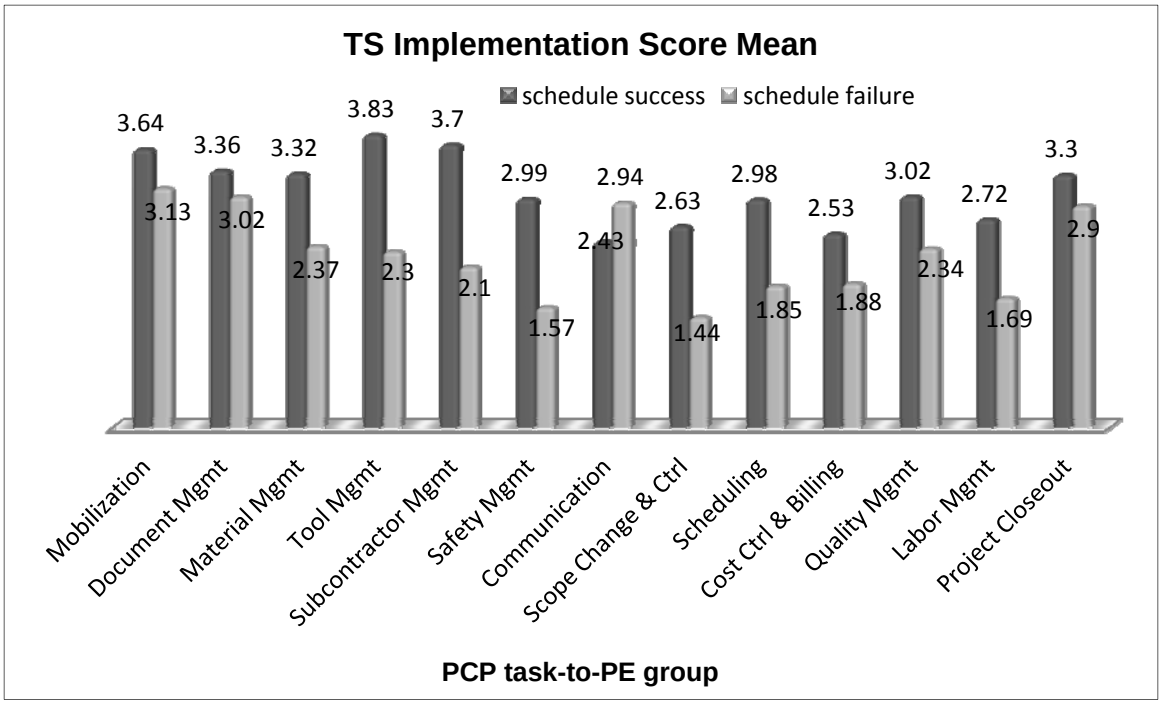

Figure 8.2: Task String Implementation Score Mean for Schedule.

An independent samples *t* test was conducted to investigate the difference in task string usage. Like the unweighted TS implementation scores, the weighted TS implementation scores are significantly different between successful and unsuccessful projects at the 95% confidence level. Specifically, the task strings within subcontractor management group may contribute significantly to schedule success. Furthermore, tool management and safety management groups showed a significant difference between

successful and unsuccessful projects at the 90% confidence level. Table 8.5 describes the results of the independent samples *t* tests for schedule performance.

#	PCP Task-to-PE Group	Projects with Schedule Success			Projects with Schedule Failure			Mean difference	*t* statistic	Sig. (two-tailed)	Eta square
		N	M	SD	N	M	SD				
1	Mobilization	42	3.64	1.56	8	3.13	1.35	0.51	–	–	–
2	Document Mgmt	42	3.36	1.75	8	3.02	1.48	0.34	–	–	–
3	Material Mgmt	42	3.32	1.67	8	2.37	1.34	0.95	–	–	–
4	Tool Mgmt	42	3.83	2.06	8	2.30	1.79	1.53	1.97	0.055	0.075
5	Subcontractor Mgmt	42	3.70	1.85	8	2.10	2.15	1.60	2.19	0.034	0.091
6	Safety Mgmt	42	2.99	2.03	8	1.57	1.98	1.42	1.82	0.075	0.065
7	Communication	42	2.43	1.83	8	2.94	1.83	-0.51	–	–	–
8	Scope Change & Ctrl	42	2.63	2.11	8	1.44	2.21	1.19	–	–	–
9	Scheduling	42	2.98	2.41	8	1.85	1.68	1.13	–	–	–
10	Cost Ctrl & Billing	42	2.53	1.48	8	1.88	1.31	0.65	–	–	–
11	Quality Mgmt	42	3.02	1.67	8	2.34	1.57	0.68	–	–	–
12	Labor Mgmt	42	2.72	2.24	8	1.69	1.94	1.03	–	–	–
13	Project Closeout	42	3.30	1.65	8	2.90	1.96	0.40	–	–	–

Table 8.5: The Effect of Weighted Task String Usage on Schedule Success.

8.6 SUMMARY OF THE EFFECTS OF TASK STRING USAGE

The purpose of this study was to investigate the effects of task string usage on project cost and schedule success. This research provides empirical evidence that supports the expectation that higher levels of task string implementation produce significant benefits. The results of this study indicated that task string implementation is critical to achieving project cost and schedule success. In particular, cost success is significantly associated with task string implementation within most of the PCP task-to PE groups at the 95% confidence level. These groups include mobilization, document

management, tool management, communication, scheduling, cost control and billing, quality management, labor management, and project closeout. On the other hand, schedule success is significantly associated with task string implementation within the subcontractor management group at the confidence level of 0.05. These results persist regardless of weight values of task strings. The results of the correlation between task strings and project success are summarized below in Table 8.6.

#	PCP task-to-PE Group	*Correlation between Task String Usage and Project Success*	
		Cost Success	Schedule Success
1	Mobilization	V	
2	Document Management	V	
3	Material Management	V	
4	Tool Management	V	V*
5	Subcontractor Management		V
6	Safety Management		V*
7	Communication	V	
8	Scope Change & Control		
9	Scheduling	V	
10	Cost Control & Billing	V	
11	Quality Management	V	
12	Labor Management	V	
13	Project Closeout	V	

*denotes the significant task strings at the confidence level of 0.10.

Table 8.4: Correlation between Task String Usage and Project Success

Chapter 9: Leveraged Effects of Task Strings on Project Success

9.1 Overview of the Analysis

The leveraged effect of task string usage on project success was investigated to test hypothesis II-(b) that task strings significantly improve the likelihood of project success as opposed to implementing either PCP or PE task individually. For the purpose of the analysis, the success rate of three different task types were computed with 50 sets of electrical project data. Using SPSS® 15.0, an analysis of variance (ANOVA) test was conducted to identify the mean difference in project success rates among task strings, and their corresponding PCP and PE tasks. The results indicated whether or not task string groups may have a significantly leveraged effect as opposed to implementing either PCP or PE task individually.

9.2 Test of Hypothesis II-(b)

This study investigated the leveraged effect of task string implementation on project performance. To compare the effect of the task string to that of its corresponding PCP and PE tasks, the task string was disassembled. As a result, three types of project tasks were identified: (1) PCP tasks, (2) PE tasks, and (3) PCP-PE task strings. Based on the probabilities of achieving successful outcomes, task strings within each PCP task-to-PE group were compared to their corresponding PCP tasks and PE tasks in terms of the probability of project success. During the analysis, hypothesis two, developed in Chapter 7, was tested. For the statistical analysis, the null and alternative hypotheses were developed as follows:

- H_0: The success rate mean of task strings within each TS group is equal to or less than that of PCP or PE task.

- H_1: The success rate mean of task strings within each TS group is greater than that of the PCP or PE task only.

To obtain robust and reliable results, the task strings for which the frequency of each PCP and PE task is greater than or equal to five were considered for the analysis of leverage effect. Thus, due to small sample size, 19 task strings with sample sizes of less than 5 were removed. A summary of the removed task strings is presented in Table 9.1.

Task Sting #	Frequency		
	Task String	PCP Task	PE Task
53	25.0	16.0	2.0*
54	25.0	17.0	2.0*
68	26.0	4.0*	14.0
147	25.0	17.0	4.0*
150	25.0	16.0	4.0*
151	25.0	12.0	4.0*
158	23.0	18.0	4.0*
163	24.0	18.0	4.0*
165	24.0	17.0	4.0*
168	22.0	19.0	4.0*
169	23.0	19.0	3.0*
172	24.0	17.0	2.0*
180	23.0	18.0	3.0*
181	23.0	19.0	3.0*
182	23.0	18.0	3.0*
215	23.0	18.0	4.0*
216	24.0	18.0	3.0*
223	24.0	18.0	4.0*
226	27.0	14.0	1.0*

*denotes tasks that were implemented fewer than five times.

Table 9.1: Task Strings with Small Sample Size.

A one-way analysis of variance (ANOVA) test was conducted to determine whether or not there is a significant difference in success rates among task strings and their corresponding PCP task and PE tasks. In the analysis, the null hypothesis was tested at the significance level of 0.05. Laven's test was conducted to identify homogeneity of variances within each of the populations. If they are heterogeneous ($p<0.05$), the Welch test and Games-Howell test were used instead because these methods do not rely on the assumption of equal variances. Prior to conducting the ANOVA test, the assumption of normality was tested using the Shapiro-Wilk test that identifies whether or not the data are normally distributed at the 95% confidence level. If the null hypothesis of normality was rejected ($p<0.05$), non-parametric alternatives, the Kruskal Wallis test and Mann-Whitney U test, could be used to further evaluate the research hypotheses.

9.3 The Leverage Effects of Task Strings on Cost Success

The focus of cost success was to identify whether there is a statistically significant difference among the three different task types in terms of probability of cost success. A one-way analysis of variance (ANOVA) test was conducted to identify the leveraged effect of task strings on cost success compared to individual implementation of PCP or PE tasks. The task strings were categorized into 13 PCP task-to-PE groups. However, two groups with a small number of task strings (less than 5) were excluded in this analysis. These groups include communication and scope and change control. As a result, the probability of task strings for cost success within the 11 PCP task-to-PE groups was compared to that of their corresponding PCP and PE tasks. The mean probabilities of three different task types for cost success are graphically presented in Figure 9.1.

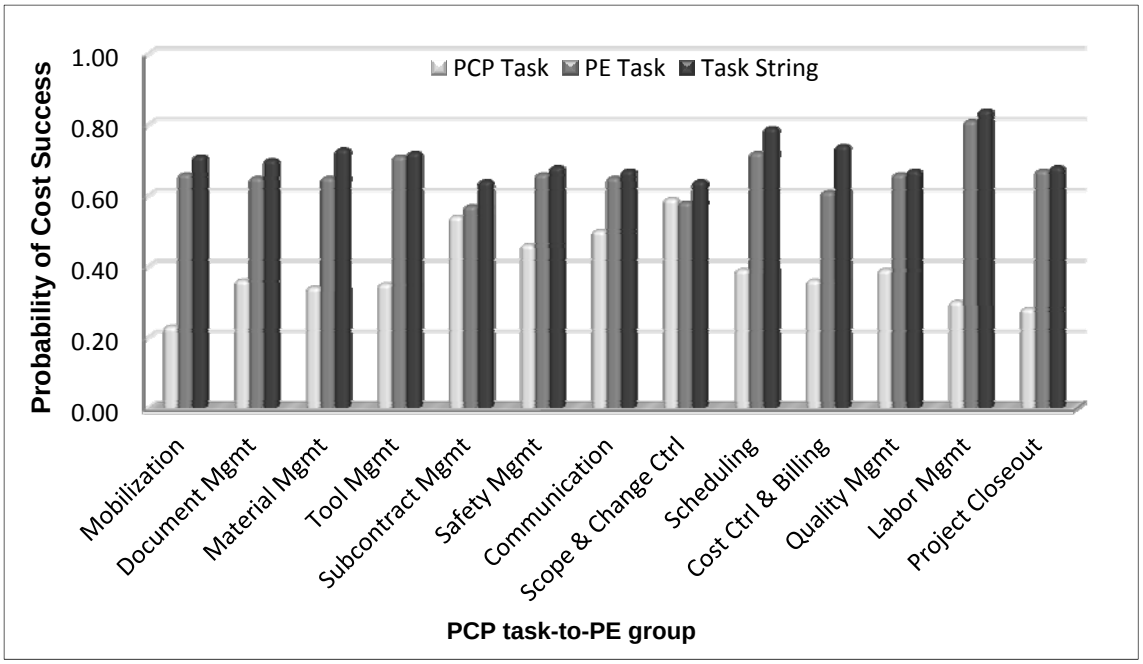

Figure 9.1: Probability of Different Task Types for Cost Success

To test the assumption of normality, the Shapiro-Wilk test was conducted, and as a result, any of the three independent variables (TS, PCP, and PE tasks) in the PCP task-to-PE groups did not show a normal distribution. These groups include material management, subcontractor management, cost control and billing, and project closeout. Thus, these groups were analyzed with the Kruskal-Wallis H test and the Mann-Whitney U tests. An ANOVA test was conducted to compare the probabilities of the three task types within the remaining PCP task-to-PE groups. Leven's test of homogeneity of variances was found not to be violated ($p > 0.05$) for three groups, including communication, scope and change control, and labor management. These groups indicated the variances of the groups are the same. The results of the analysis revealed that the cost success probability differed significantly across the different task types within labor management group at the 95% confidence level, $F(2,21)=77.299$, $p=0.000$.

For other groups, Leven's test of homogeneity of variances was found to be violated ($p< 0.05$). Therefore, the Welch test was used, because the method does not rely on the assumption of equal variances. The results of the test revealed that the cost success probability differed significantly across the different task types at the 95% confidence level. These groups include mobilization, $F(2,26.431)=196.299$, $p=0.000$, document management, $F(2,53.120)=100.276$, $p=0.000$, tool management, $F(2,19.022)=106.673$, $p=0.000$, safety management, $F(2, 8.320)=33.852$, $p=0.000$, scheduling, $F(2,23.401)=154.977$, $p=0.000$, and quality management, $F(2,14.588)=10.934$, $p=0.001$. The results of the ANOVA test are presented in Table 9.2.

	PCP Task for Cost Success			PE Task for Cost Success			Task String for Cost Success				
PCP task-to-PE Group	N	Prob. Mean	SD	N	Prob. Mean	SD	N	Prob. mean	SD	F	Sig.
Mobilization*	18	0.23	0.10	18	0.66	0.14	18	0.71	0.04	196.299	0.000
Document Mgmt*	33	0.36	0.13	33	0.65	0.11	33	0.70	0.05	100.276	0.000
Tool Mgmt*	12	0.35	0.05	12	0.71	0.14	12	0.72	0.09	58.60	0.000
Safety Mgmt*	11	0.46	0.06	11	0.66	0.19	11	0.68	0.06	33.852	0.000
Scheduling*	15	0.39	0.04	15	0.72	0.16	15	0.79	0.08	154.977	0.000
Quality Mgmt*	9	0.39	0.17	9	0.66	0.09	9	0.67	0.07	10.934	0.001
Labor Mgmt	8	0.30	0.08	8	0.81	0.13	8	0.84	0.07	77.299	0.000

*denotes task string groups with heterogeneity of variance (Welch test).

Table 9.2: The Results of the ANOVA Test for Cost Success.

To determine which specific task groups differ from each other, pairwise comparisons between different task types were also investigated using the Tukey-Kramer method. These pairwise comparisons were only conducted for the PCP task-to-PE groups that showed significant difference in the probability of cost success. Tukey post hoc comparisons of the three task types indicated that task strings within all of the task string groups achieved a greater probability of cost success than PCP tasks at the confidence

level of 0.05. On the other hand, the task strings did not achieve a statistically greater probability for cost success than PE tasks. Table 9.3 summarizes the results of pairwise comparisons for cost success. As for the PCP task-to-PE groups that did not meet homogeneity of variances, the Games-Howell method was also used for post-hoc comparisons. Games-Howell post-hoc comparisons of the three different task types indicated that task strings had a significantly greater cost success than PCP tasks. However, they also did not achieve a significant difference from PE tasks.

	Task String - PCP Task		*Task String - PE Task*		*PE Task - PCP Task*	
PCP task-to-PE Group	Mean Difference	Sig.	Mean Difference	Sig.	Mean Difference	Sig.
Mobilization*	0.48	0.000	0.05	-	0.44	0.000
Document Mgmt*	0.33	0.000	0.05	-	0.28	0.000
Tool Mgmt*	0.38	0.000	0.01	-	0.37	0.000
Safety Mgmt*	0.21	0.000	0.02	-	0.19	0.019
Scheduling*	0.40	0.000	0.07	-	0.33	0.000
Quality Mgmt*	0.03	0.002	0.02	-	0.43	0.000
Labor Mgmt	0.54	0.000	0.03	-	0.50	0.000

*denotes task string groups with heterogeneity of variance (Games Howell test).

Table 9.3: The Results of Pairwise Comparisons for Cost Success.

A non-parametric analysis, the Kruskal Wallis H test, was also conducted for the non-normal variables. These included material management, subcontractor management, cost control and billing, and project closeout groups. The results indicate that cost success was significantly different across the three different task types within all the groups at the 95% confidence level. Table 9.4 shows the results of the Kruskal Wallis H test.

PCP task-to-PE Group	*PCP Task for Cost Success*		*PE Task for Cost Success*		*Task String for Cost Success*		Chi-Square	df	Sig.
	N	Mean Rank	N	Mean Rank	N	Mean Rank			
Material Mgmt	37	19.99	37	61.91	37	86.11	80.052	2	0.000
Subcontract Mgmt	37	38.66	37	50.08	37	79.26	31.455	2	0.000
Cost Ctrl & Billing	26	14.58	26	40.48	26	63.44	60.581	2	0.000
Project Closeout	8	4.75	8	15.25	8	17.50	14.878	2	0.001

Table 9.4: The Results of Kruskal Wallis Test by Task String Group.

For post-hoc comparisons, the Mann-Whitney U test was subsequently conducted. In this analysis Bonferroni's correction was used to reduce type I errors for multiple comparisons. The analysis results indicate that task string groups achieved a greater cost success with task strings than with PCP and PE tasks, particularly in material management, subcontractor management, and cost control and billing groups. In the project closeout group, task strings had greater cost success than PCP tasks, but not PE tasks. Tables 9.5-6 show the results of Mann-Whitney U test for cost success.

PCP task-to-PE Group	Task String for Cost Success			PCP Task for Cost Success			z-value	Sig.
	N	Mean rank	Sum of Ranks	N	Mean rank	Sum of Ranks		
Material Mgmt	37	19.00	703.00	37	56.00	2072.00	-7.40	0.000
Subcontract Mgmt	37	50.72	1876.50	37	24.28	898.50	-5.292	0.000
Cost Ctrl & Billing	26	39.48	1026.50	26	13.52	351.50	-6.18	0.000
Project Closeout	8	12.50	100.00	8	4.50	36.00	-3.371	0.002

Table 9.5: The Results of Mann-Whitney U Test for Cost (TS *vs*. PCP).

PCP task-to-PE Group	Task String for Cost Success			PE Task for Cost Success			z-value	Sig.
	N	Mean rank	Sum of Ranks	N	Mean rank	Sum of Ranks		
Material Mgmt	37	49.11	1817.00	37	25.89	958.00	-4.65	0.000
Subcontract Mgmt	37	47.54	1759.00	37	27.46	1016.00	-4.03	0.000
Cost Ctrl & Billing	26	37.46	974.00	26	15.54	404.00	-5.22	0.000
Project Closeout	8	9.50	76.00	8	7.50	60.00	-0.845	-

Table 9.6: The Results of Mann-Whitney U Test for Cost (TS *vs*. PE).

9.4 THE LEVERAGE EFFECTS OF TASK STRINGS ON SCHEDULE SUCCESS

The analysis of schedule success focused on identifying whether or not there is a significant difference among the different task types in terms of the probability of schedule success. A one-way analysis of variance (ANOVA) test was conducted to compare the mean values of schedule success with task strings and with their corresponding PCP and PE tasks. The mean probabilities of different task types are graphically shown in Figure 9.2.

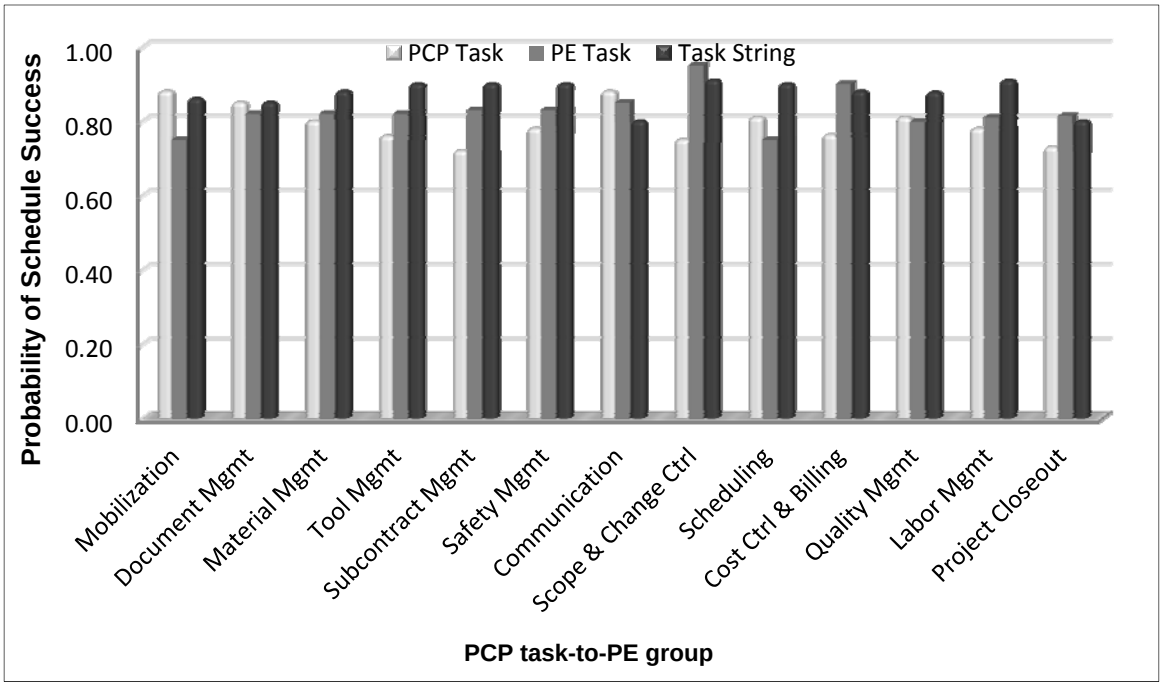

Figure 9.2: Probability of Different Task Types for Schedule Success.

Leven's test of homogeneity of variances was found not to be violated ($p > 0.05$) for the PCP task-to-PE groups of quality management and labor management. The results of the ANOVA test showed that schedule success was significantly different across the different task types within labor management at the 95% confidence level,

F(2,21)=7.703, p=0.013. To analyze the task strings that showed heterogeneity variances, the Welch test was conducted. The results showed that schedule success was significantly different across the three groups at the 95% confidence level. These groups included material management, F(2, 63.927)=14.064, p=0.000, tool management, F(2, 18.908)=16.167, p=0.000, safety, F(2, 16.435)=13.653, p=0.000, scheduling, F(2, 24.270)=23.306, p=0.000, and project closeout, F(2, 11.388)=5.225, p=0.025. Table 9.7 summarizes the results of the analysis for schedule success.

	PCP Task for Schedule Success			*PE Task for Schedule Success*			*Task String for Schedule Success*				
PCP task-to-PE Group	N	Prob. Mean	SD	N	Prob. Mean	SD	N	Prob. mean	SD	F	Sig.
Material Mgmt*	37	0.80	0.09	37	0.82	0.12	37	0.88	0.05	14.06	0.000
Tool Mgmt*	12	0.76	0.08	12	0.82	0.11	12	0.90	0.04	16.17	0.000
Safety Mgmt*	11	0.78	0.02	11	0.83	0.05	11	0.90	0.03	13.653	0.000
Scheduling*	15	0.81	0.08	15	0.75	0.08	15	0.90	0.03	23.306	0.000
Quality Mgmt	9	0.81	0.07	9	0.80	0.10	9	0.88	0.04	-	-
Labor Mgmt	8	0.78	0.10	8	0.81	0.10	8	0.91	0.04	5.38	0.013
Project Closeout*	8	0.73	0.10	8	0.81	0.09	8	0.80	0.09	5.225	0.025

*denotes task string groups with heterogeneity of variance (Welch test).

Table 9.7: The Results of the ANOVA test for Schedule Success.

The Tukey-Kramer method was used to determine which specific groups differ from each other. Tukey post-hoc comparisons of the three groups showed that task strings (M=0.91, 95% CI [0.87, 0.95]) had a significantly higher schedule success than the PCP tasks (M=0.78, 95% CI [0.69, 0.86]) in the labor management group. However, they did not achieve greater schedule success than PE tasks. For task string groups with heterogeneity of variances, the Games-Howell method was also conducted for post-hoc comparisons. Games-Howell post-hoc comparisons of the three different task types showed that task strings (M=0.88, 95% CI[0.87, 0.90], M=0.90, 95% CI[0.88,0.92])

achieved a significantly higher cost success than PCP tasks (M=0.82, 95% CI[0.77, 0.85], M=0.81, 95% CI[0.77, 0.85]) and PE tasks (M=0.83, 95% CI[0.80, 0.87], M=0.75, 95% CI[0.77, 0.85]) in material management and scheduling groups respectively. However, other task strings only had a greater schedule success than PCP tasks, and they did not have a higher schedule success than PE tasks. Table 9.8 summarizes the results of pairwise comparisons for schedule success.

	Task String - PCP Task		*Task String - PE Task*		*PE Task - PCP Task*	
PCP task-to-PE Group	Mean Difference	Sig.	Mean Difference	Sig.	Mean Difference	Sig.
Material Mgmt*	0.08	0.000	0.07	0.005	0.01	-
Tool Mgmt*	0.14	0.000	0.08	-	0.06	-
Safety Mgmt*	0.12	0.000	0.07	-	0.05	-
Scheduling*	0.09	0.003	0.14	0.000	-0.06	-
Labor Mgmt	0.13	0.013	0.10	-	0.03	-
Project Closeout*	0.12	0.028	0.04	-	0.08	-

*denotes task string groups with heterogeneity of variance (Games-Howell test).

Table 9.8: The Results of Pairwise Comparisons for Schedule Success.

A non-parametric analysis, the Kruskal Wallis H test, was also conducted for the non-normal variables. These PCP task-to-PE groups included mobilization, document management, subcontractor management, and cost control and billing. The results indicate that schedule success was significantly different across the three different task types within subcontractor management and cost control and billing groups at the 95% confidence level. Table 9.9 shows the results of the Kruskal Wallis H test for schedule success.

PCP task-to-PE Group	*PCP Task for Schedule Success*		*PE Task for Schedule Success*		*Task String for Schedule Success*		Chi-Square	df	Sig.
	N	Mean Rank	N	Mean Rank	N	Mean Rank			
Mobilization	18	31.08	18	20.81	18	30.61	4.947	2	-
Document Mgmt	33	50.29	33	45.38	33	54.33	1.615	2	-
Subcontractor Mgmt	37	28.92	37	57.62	37	81.46	49.512	2	0.000
Cost Ctrl & Billing	26	21.83	26	51.10	26	45.58	24.548	2	0.000

Table 9.9: The Results of Pairwise Comparisons for Schedule Success.

For post-hoc comparisons, the Mann-Whitney U test was subsequently conducted. In this analysis Bonferroni's correction was used to reduce type I errors for multiple comparisons. The analysis results indicate that task strings within the subcontractor management group achieved greater schedule success than both PCP and PE tasks at the 95% confidence level. The task strings in cost control and billing group had a higher schedule success than PCP tasks; however, there was no significant difference in schedule success between task strings and PE tasks at the 95% confidence level. Tables 9.10-11 show the results of Mann-Whitney U test for cost success.

PCP task-to-PE Group	Task String for Schedule Success			PCP Task for Schedule Success			z-value	Sig.
	N	Mean rank	Sum of Ranks	N	Mean rank	Sum of Ranks		
Subcontractor Mgmt	37	54.49	2016.00	37	20.51	759.00	-6.80	0.000
Cost Ctrl & Billing	26	35.02	910.50	26	17.98	467.50	-4.06	0.000

Table 9.10: The Results of Mann-Whitney U Test for Schedule (TS *vs*. PCP).

PCP task-to-PE Group	Task String for Schedule Success			PE Task for Schedule Success			z-value	Sig
	N	Mean rank	Sum of Ranks	N	Mean rank	Sum of Ranks		
Subcontractor Mgmt	37	45.97	1701.00	37	29.03	1074.00	-3.39	0.001
Cost Ctrl & Billing	26	24.06	625.50	26	28.94	752.50	-	-

Table 9.11: The Results of Mann-Whitney U Test for Schedule (TS *vs*. PE).

9.5 SUMMARY OF THE LEVERAGED EFFECTS OF TASK STRINGS

The leveraged effects of task strings on project success were investigated to test hypothesis two that task strings significantly improve the likelihood of project success as opposed to implementing PCP or PE task individually. As a result, task strings had greater cost success than individual implementation of both PCP and PE tasks in the PCP task-to-PE groups of material management, subcontractor management, and cost control and billing. As for schedule success, the material management, subcontractor management, scheduling, and cost control and billing task string groups achieved a greater schedule success with task strings than with both PCP and PE tasks. The results of the leveraged effects on project success are summarized below in Table 9.12.

#	PCP task-to-PE group	Cost Success		Schedule Success	
		TS » PCP	TS» PE	TS » PCP	TS» PE
1	Mobilization	V			
2	Document Management	V			
3	Material Management	V	V	V	V
4	Tool Management	V		V	
5	Subcontractor Management	V	V	V	V
6	Safety Management	V		V	
7	Communication	N/A	N/A	N/A	N/A
8	Scope Change & Control	N/A	N/A	N/A	N/A
9	Scheduling	V		V	V
10	Cost Control & Billing	V	V	V	
11	Quality Management	V			
12	Labor Management	V		V	
13	Project Closeout	V		V	

Table 9.12: Summary of the Leveraged Effects on Project Success.

Chapter 10: Ranking of Task Strings for Cost and Schedule Success

10.1 Overview of the Analysis

The focus of this chapter is to identify the high-value task strings that have the greatest effect on project success. To determine the ranking of the task strings, a simple correlation analysis using SPSS® 15 was employed. These task strings were further analyzed to examine the leveraged effect of each task string on project success as opposed to implementing either PCP or PE task individually. To investigate the leveraged effects, a binary regression analysis was conducted. Based on the results of the analyses, task strings ranked in three string categories: (1) basic task string, (2) better task string, and (3) best task string. During the analysis, hypothesis three, developed in Chapter 7, was tested. As a result, a list of the ranked task strings was generated and summarized.

10.2 The Criteria for Selecting the Ranked Task Strings

The high-value task strings have a significant association with project success and at the same time have a significantly leveraged effect on project performance as opposed to implementing either PCP or PE task individually. To examine the effects of the task strings, two statistical analyses were conducted: a phi correlation analysis and a logistic regression analysis. The phi correlation analysis identified the simple effects of task strings on project performance, while the logistic regression analysis determined the leveraged effects of task strings on project performance compared to that of either PCP or PE task. As a result of the analysis, 239 task strings ranked in three levels of task strings: (1) basic task string, (2) better task string, and (3) best task string. The decision criteria for selecting basic/better/best task strings are described below in Figure 10.1.

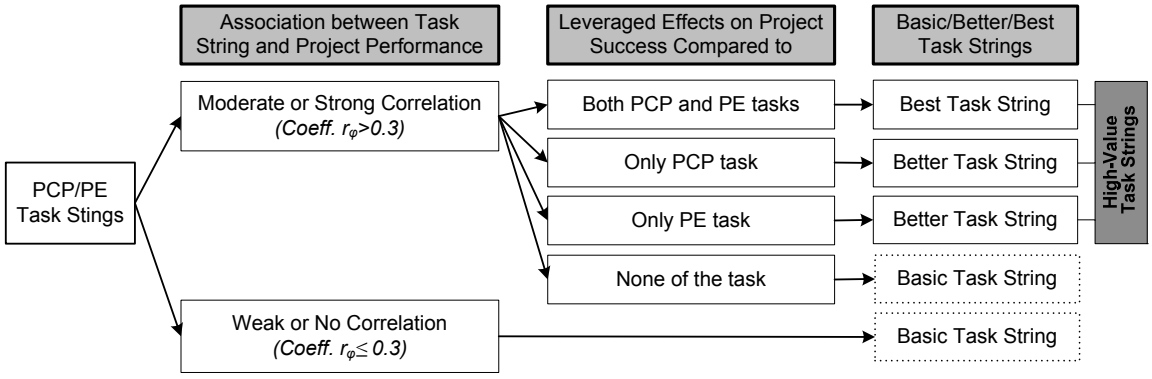

Figure 10.1: Decision Criteria for Ranking of Task Strings.

Best task strings have a significantly positive association with project success and at the same time have a significant leveraged effect on project success compared to individual implementation of both PCP and PE tasks. Better task strings have a significantly positive correlation to project success and also have a significantly leveraged effect on project success as opposed to implementing either PCP or PE task individually. Basic task strings may have a significant association with project success, but result in no significantly leveraged effect on project success compared to that of either PCP or PE task. The other task strings that are not significantly associated with project success or are weakly associated with project success are also classified as basic task strings. Although these task strings showed no significant leveraged effects on project success, implementation of these task strings is recommended by electrical professionals.

10.3 TEST OF HYPOTHESIS III

This study focused on investigating the high-value task strings that have greatest effect on project success. To investigate the association of task strings with project success, a simple correlation analysis was conducted. A phi correlation analysis

examined whether or not task strings were positively correlated with cost and schedule success at the 95% confidence level. The analysis produced the phi coefficient that represents the strength of the relationship between task string and project performance. As a rule of thumb, a strong correlation has a phi coefficient value of between 0.7 and 1.0. In a moderate correlation, the phi coefficient ranges from 0.3 to 0.7. A weak or no correlation represents the coefficient value of between 0 and 0.3. In this study, a phi coefficient value of greater than 0.3 was used as a cut off value. Correlation coefficients are generally interpreted as shown in Table 10.1.

#	Coeff. r_φ	Interpretation
1	-1.0 to -0.7	Strong negative association
2	-0.7 to -0.3	Moderate negative association
3	-0.3 to +0.3	Weak or no association
4	+0.3 to +0.7	Moderate positive association
5	+0.7 to 1.0	Strong positive association

Table 10.1: Interpretation of Correlation Coefficient.

In addition, these task strings were further analyzed to identify how much project success can be improved compared to implementing either PCP or PE task individually. To investigate the leveraged effects of these task strings, a binary logistic analysis was conducted for each task string. The binary logistic analysis typically explores the relative effects of independent variables on a dichotomous dependent variable. In this analysis, the effect of a task string on project success was identified by comparing it with that of its corresponding PCP and PE tasks. The analysis basically produces a logistic regression equation in which the coefficient is generally interpreted as the change in the logit of the probability associated with a unit change in the predictor holding all other predictors

constant. As a result, comparison of the coefficient of each task type determined the relative effects on project success. Consequently, the ranking of PCP-PE task strings were determined based on their effects on project success. During the analysis, hypothesis three was tested as shown below:

For the simple correlation analysis,

- H_0: There is no relationship between task strings and project success.
- H_1: There is a significant relationship between task strings and project success.

For the binary logistic regression analysis,

- H_0: The probability of the task string for project success is equal to or less than that of either PCP or PE task.
- H_1: The probability of the task string for project success is greater than that of either PCP or PE task.

10.4 CORRELATION BETWEEN TASK STRING AND PROJECT PERFORMANCE

A phi correlation analysis was conducted to identify whether or not task strings have a significantly positive association with cost and schedule success. In this analysis, if the frequency of any task included in the three categories is less than 5 out of the 50 electrical projects, then the task string, including its corresponding PCP and PE tasks, was excluded from the analysis because of small sample size. As a result of the analysis, 55 task strings that are moderately correlated with cost success are summarized in Table 10.2.

Task String #	Corr. Coeff. (r_φ)	Sig. (*p*)	Task String #	Corr. Coeff. (r_φ)	Sig. (*p*)
1	0.333*	0.018	164	0.414**	0.003
2	0.362**	0.010	166	0.447**	0.001
4	0.370**	0.008	167	0.385**	0.006
8	0.417**	0.003	171	0.555**	0.000
9	0.333*	0.018	173	0.364**	0.009
14	0.311*	0.028	177	0.311*	0.028
15	0.448**	0.001	178	0.344*	0.014
24	0.333*	0.018	183	0.333*	0.018
31	0.323*	0.022	191	0.311*	0.028
34	0.360*	0.010	192	0.345*	0.014
35	0.408**	0.003	193	0.345*	0.014
36	0.333*	0.018	194	0.364**	0.009
47	0.311*	0.028	197	0.345*	0.014
50	0.360*	0.010	199	0.344*	0.014
52	0.327*	0.020	207	0.327*	0.020
56	0.529**	0.000	208	0.303*	0.033
59	0.333*	0.018	209	0.327*	0.020
73	0.311*	0.028	210	0.445**	0.001
75	0.333*	0.018	211	0.370**	0.008
76	0.323*	0.022	212	0.333*	0.018
77	0.323*	0.022	214	0.311*	0.028
78	0.311*	0.028	224	0.447**	0.001
79	0.380**	0.006	225	0.417**	0.003
80	0.370**	0.008	227	0.508**	0.000
100	0.471**	0.001	228	0.500**	0.000
101	0.311*	0.028	231	0.414**	0.003
103	0.387**	0.006	236	0.323*	0.022
162	0.313*	0.027			

*denotes statistically significant at the 95% confidence level (i.e. α=0.05).
**denotes statistically significant at the 99% confidence level (i.e. α=0.01).

Table 10.2: Task Strings Moderately Correlated with Cost Success.

Subsequently, the effects of the task string on schedule success were also investigated. As a result of the analysis, 12 task strings were moderately correlated with schedule success at the 95% confidence level. The summary of the task strings correlated with schedule success is presented below in Table 10.3.

Task String #	Corr. Coeff. (r_φ)	Sig. (*p*)
24	0.312*	0.028
52	0.313*	0.027
59	0.356*	0.011
74	0.310*	0.028
102	0.327*	0.020
106	0.402**	0.004
107	0.402**	0.004
112	0.312*	0.028
123	0.312*	0.028
126	0.402**	0.004
190	0.310*	0.028
230	0.342*	0.015

*denotes statistically significant at the 95% confidence level (i.e. α=0.05).
**denotes statistically significant at the 99% confidence level (i.e. α=0.01).

Table 10.3: The Task Strings Correlated with Schedule Success.

10.4.1 Leveraged Effects of Task Strings on Cost Success

The purpose of the binary logistic regression analysis was to identify the high-value task strings that have a greater effect on cost success as opposed to either that of PCP or PE tasks. Accordingly, each task string was designated as a reference category in the analysis. The 55 task strings that are associated with cost success were analyzed and the odd ratios of their according PCP and PE tasks were compared. The results of the logistic regression analysis were summarized according to their effects on cost success compared to that of PCP or PE tasks. Table 10.4 shows the results of the task strings that have a significantly greater effect on cost success than both PCP and PE tasks.

The analysis results indicated that the odds of cost success compared to cost failure were significantly increased when the task string was implemented compared to implementing either PCP or PE task. In task string #5, for example, the odds ratio of

individual implementation of PCP task #11 is 0.080 [exp (-2.526)]. This means the odds of cost success compared to cost failure were significantly decreased by a factor of 0.080 when PCP 3 task was individually implemented, not in conjunction with PE task #2. Consequently, the odds of task string #5 (implementing both PCP task #11 and PE task #7) producing cost success were 12.5 times greater than the odds of success with individual implementation of PCP task #11. Similarly, the odds of cost success using task string #5 were 5.2 times greater than the odds for success with individual implementation of PE task #7. In summary, the odds of each of the five task strings resulting in success were at least 5 times greater than the odds of success produced by implementing either of its corresponding PCP or PE tasks.

Task String #	PCP/PE Task	Total Samples (N)	B	SE	Wald	df	Sig.	Odds Ratio Exp(B)	Added Value [1/Exp(B)]
5	PCP3	5	-2.526	1.190	4.508	1	0.034	0.080	12.5
	PE2	8	-1.650	0.836	3.900	1	0.048	0.192	5.2
56	PCP11	17	-2.608	0.892	8.550	1	0.003	0.074	13.5
	PE17	6	-3.861	1.324	8.504	1	0.004	0.021	47.6
171	PCP11	19	-3.209	1.128	8.098	1	0.004	0.040	25
	PE58	7	-3.178	1.280	6.163	1	0.013	0.042	23.8
210	PCP38	15	-3.332	1.171	8.096	1	0.004	0.036	27.7
	PE68	11	-2.821	1.199	5.535	1	0.019	0.060	16.7
231	PCP38	13	-2.826	0.963	8.607	1	0.003	0.059	16.9
	PE78	9	-1.792	1.008	3.158	1	0.076	0.167	6.0

Notes: Dependent Variable: Cost Failure=0, Cost Success=1 (predicted)
Covariate: PCP Task=1, PE Task=2, and Task String=3 (the reference)

Table 10.4: Leveraged Effects on Cost Success (TS *vs.* PCP & PE).

Table 10.5 summarizes the results of the task strings that have significantly greater effects on cost success than PCP tasks alone. Overall, the odds of the task string resulting in cost success were at least 5 times greater than the odds of its corresponding

PCP task producing success. However, these task strings did not show significantly greater effects than PE tasks at the 95% confidence level.

Task String #	PCP/PE Task	Total Samples (N)	B	SE	Wald	df	Sig.	Odds Ratio Exp(B)	Added Value [1/Exp(B)]
1	PCP3	11	-1.992	0.793	6.313	1	0.012	0.136	7.3
	PE1	8	-0.501	0.839	0.356	1	-	-	-
2	PCP7	9	-3.060	1.130	7.329	1	0.007	0.047	21.3
	PE1	5	-0.575	0.993	0.336	1	-	-	-
8	PCP11	8	-1.700	0.848	4.018	1	0.045	0.183	5.5
	PE2	8	-1.190	0.828	2.062	1	-	-	
9	PCP31	7	-2.803	1.156	5.877	1	0.015	0.061	16.3
	PE2	8	-0.501	0.839	0.356	1	-	-	
14	PCP10	6	-2.659	1.180	5.077	1	0.024	0.070	14.3
	PE7	14	-0.762	0.696	1.199	1	-	-	
24	PCP30	11	-1.992	0.793	6.313	1	0.012	0.136	7.3
	PE8	8	-1.012	0.819	1.526	1	-	-	-
31	PCP3	9	-2.191	0.893	6.020	1	0.014	0.112	8.9
	PE10	8	-0.427	0.829	0.266	1	-	-	-
34	PCP10	7	-2.996	1.176	6.488	1	0.011	0.050	20.0
	PE10	14	-0.916	0.713	1.652	1	-	-	-
36	PCP31	7	-2.803	1.156	5.877	1	0.015	0.061	16.3
	PE10	10	-0.606	0.766	0.626	1	-	-	
47	PCP3	14	-1.638	0.710	5.321	1	0.021	0.194	5.2
	PE12	5	0.336	1.201	0.078	1	-	-	-
50	PCP30	15	-1.897	0.719	6.966	1	0.008	0.150	6.7
	PE12	6	-0.511	0.983	0.270	1	-	-	-
52	PCP2	16	-2.051	0.819	6.267	1	0.012	0.129	7.8
	PE17	10	-1.135	0.906	1.568	1	-	-	-
59	PCP30	21	-1.674	0.712	5.528	1	0.019	0.188	5.3
	PE17	7	-1.099	0.946	1.347	1	-	-	
73	PCP30	14	-1.638	0.710	5.321	1	0.021	0.194	5.2
	PE22	8	-1.050	0.832	1.591	1	-	-	

Notes: Dependent Variable: Cost Failure=0, Cost Success=1 (predicted)
Covariate: PCP Task=1, PE Task=2, and Task String=3 (the reference)

Table 10.5: Leveraged Effects on Cost Success (TS *vs.* PCP).

Task String #	PCP/PE Task	Total Samples (N)	B	SE	Wald	df	Sig.	Odds Ratio Exp(B)	Added Value [1/Exp(B)]
75	PCP38	10	-2.234	0.888	6.326	1	0.012	0.107	9.3
	PE22	15	-1.253	0.762	2.704	1	-	-	-
76	PCP3	9	-2.191	0.893	6.020	1	0.014	0.112	8.9
	PE23	7	-0.022	0.924	0.001	1	-	-	-
77	PCP7	10	-2.325	0.883	6.931	1	0.008	0.098	10.2
	PE23	7	-0.022	0.924	0.001	1	-	-	-
78	PCP10	6	-2.659	1.180	5.077	1	0.024	0.070	14.3
	PE23	12	-0.357	0.754	0.224	1	-	-	
80	PCP30	10	-2.442	0.891	7.518	1	0.006	0.087	11.5
	PE23	8	-0.545	0.838	0.424	1	-	-	-
100	PCP10	15	-2.773	0.929	8.913	1	0.003	0.062	16.0
	PE29	10	-1.132	1.019	1.462	1	-	-	-
101	PCP30	18	-1.638	0.710	5.321	1	0.021	0.194	5.1
	PE29	5	0.560	1.180	0.225	1	-	-	-
103	PCP38	12	-2.655	0.924	8.251	1	0.004	0.070	14.3
	PE29	10	-1.086	0.841	1.669	1	-	-	-
162	PCP3	19	-1.542	0.689	5.010	1	0.025	0.214	4.7
	PE57	6	0.386	1.208	0.102	1	-	-	-
164	PCP10	16	-2.526	0.913	7.655	1	0.006	0.080	12.5
	PE57	11	-1.455	0.980	2.207	1	-	-	-
166	PCP31	16	-2.580	0.824	9.793	1	0.002	0.076	13.2
	PE57	7	-1.504	0.986	2.327	1	-	-	-
167	PCP38	14	-2.534	0.939	7.274	1	0.007	0.079	12.6
	PE57	12	-1.253	0.973	1.658	1	-	-	-
173	PCP31	16	-1.958	0.759	6.660	1	0.010	0.141	7.1
	PE58	5	-0.061	1.249	0.002	1	-	-	-
177	PCP30	14	-1.638	0.710	5.321	1	0.021	0.194	5.2
	PE60	5	-0.644	1.013	0.405	1	-	-	
178	PCP31	14	-1.869	0.753	6.163	1	0.013	0.154	6.5
	PE60	9	-1.058	0.840	1.586	1	-	-	-
183	PCP31	17	-1.743	0.745	5.470	1	0.019	0.175	5.7
	PE61	6	-0.693	1.031	0.452	1	-	-	
191	PCP10	5	-2.659	1.180	5.077	1	0.024	0.070	14.3
	PE64	10	-0.644	0.781	0.681	1	-	-	
192	PCP12	7	-3.045	1.155	6.952	1	0.008	0.048	21.0
	PE64	10	-0.693	0.779	0.791	1	-	-	-
193	PCP27	9	-2.485	0.903	7.572	1	0.006	0.083	12.0
	PE64	10	-0.693	0.779	0.791	1	-	-	-

Notes: Dependent Variable: Cost Failure=0, Cost Success=1 (predicted)
Covariate: PCP Task=1, PE Task=2, and Task String=3 (the reference)

Table 10.5: Leveraged Effects on Cost Success (TS *vs.* PCP) (Continued).

Task String #	PCP/PE Task	Total Samples (N)	B	SE	Wald	df	Sig.	Odds Ratio Exp(B)	Added Value [1/Exp(B)]
194	PCP38	8	-2.700	0.976	7.658	1	0.006	0.067	14.9
	PE64	17	-1.090	0.743	2.155	1	-	-	-
197	PCP12	8	-3.045	1.155	6.952	1	0.008	0.048	21.0
	PE65	11	-0.916	0.746	1.507	1	-	-	-
199	PCP38	7	-3.073	1.193	6.639	1	0.010	0.046	21.6
	PE65	16	-1.030	0.714	2.081	1	-	-	-
207	PCP10	16	-1.792	0.812	4.874	1	0.027	0.167	6.0
	PE68	9	-1.317	0.925	2.030	1	-	-	
208	PCP12	17	-1.678	0.748	5.035	1	0.025	0.187	5.3
	PE68	7	-1.034	0.949	1.188	1	-	-	
209	PCP27	21	-1.828	0.774	5.577	1	0.018	0.161	6.2
	PE68	9	-1.317	0.925	2.030	1	-	-	
211	PCP3	10	-2.442	0.891	7.518	1	0.006	0.087	11.5
	PE72	5	0.330	1.191	0.077	1	-	-	-
212	PCP7	12	-2.110	0.784	7.242	1	0.007	0.121	8.2
	PE72	6	0.598	1.171	0.261	1	-	-	-
214	PCP31	10	-1.897	0.818	5.379	1	0.020	0.150	6.7
	PE72	9	0.203	0.914	0.049	1	-	-	-
224	PCP9	19	-3.114	0.840	13.739	1	0.000	0.044	22.5
	PE77	7	0.000	1.247	0.000	1	-	-	-
225	PCP10	13	-2.546	0.868	8.602	1	0.003	0.078	12.8
	PE77	8	0.211	1.239	0.029	1	-	-	-
227	PCP31	14	-3.196	0.899	12.651	1	0.000	0.041	24.4
	PE77	5	-0.511	1.278	0.160	1	-	-	-
228	PCP38	13	-3.977	1.223	10.571	1	0.001	0.019	53.4
	PE77	11	-1.792	1.233	2.111	1	-	-	-
236	PCP3	9	-2.191	0.893	6.020	1	0.014	0.112	8.9
	PE82	9	-0.715	0.778	0.846	1	-	-	-

Notes: Dependent Variable: Cost Failure=0, Cost Success=1 (predicted)
Covariate: PCP Task=1, PE Task=2, and Task String=3 (the reference)

Table 10.5: Leveraged Effects on Cost Success (TS *vs.* PCP) (Continued).

10.4.2 Leveraged Effects of Task Strings on Schedule Success

This analysis focused on identifying the ranked task strings that have a significantly greater effect on schedule success. Based on the results of a correlation analysis, 12 task strings that were associated with schedule success were examined using a binary logistic regression analysis. Similar to the cost success analysis, each task string

was designated as a reference category to identify relative effects of task strings as opposed to either PCP or PE task. The results of the logistic regression analysis were summarized according to their effects on schedule success compared to that of PCP or PE tasks. Table 10.6 shows the results of the effects of task strings on schedule success compared to that of PCP or PE tasks.

Task String #	PCP/PE Task	Total Samples (N)	B	SE	Wald	df	Sig.	Odds Ratio Exp(B)	Added Value [1/Exp(B)]
24	PCP30	11	-1.658	0.997	2.766	1	-	0.190	-
	PE8	8	-2.128	1.034	4.237	1	0.040	0.119	8.4
74	PCP31	13	-1.932	1.215	2.526	1	-	0.145	-
	PE22	11	-2.576	1.198	4.619	1	0.032	0.076	13.1
106	PCP7	12	-3.219	1.183	7.401	1	-	0.040	-
	PE31	5	-2.708	1.335	4.112	1	0.043	0.067	14.9
107	PCP9	12	-2.959	1.175	6.347	1	0.012	0.052	19.2
	PE31	9	-2.043	1.296	2.485	1	-	0.130	-
123	PCP31	7	-1.723	1.112	2.402	1	-	0.179	-
	PE32	11	-2.079	0.964	4.657	1	0.031	0.125	8.0
126	PCP7	13	-2.862	1.166	6.021	1	0.014	0.057	17.5
	PE33	5	-2.927	1.367	4.583	1	0.032	0.054	18.5

Notes: Dependent Variable: Schedule Failure=0, Schedule Success=1 (predicted)
Covariate: PCP Task=1, PE Task=2, and Task String=3 (the reference)

Table 10.6: Leveraged Effects on Schedule Success (TS vs. PCP or PE).

The analysis results indicated that the odds of schedule success compared to cost failure were significantly increased when the task string was implemented compared to implementing either PCP or PE task. In task string #126, for example, the odds ratio of individual implementation of PCP task #31 is 0.014 [exp (-2.852)]. This means the odds of cost success compared to cost failure were significantly decreased by a factor of 0.014 when PCP #31 task was individually implemented, not in conjunction with PE task #58. Consequently, the odds of task string #126 (implementing both PCP task #31 and PE task

#58) producing schedule success were 17.5 times greater than the odds of success with individual implementation of PCP task #31. Similarly, the odds of schedule success using task string #126 were 18.5 times greater than the odds of success with individual implementation of PE task #58. In summary, the odds of success with each of the six task strings were at least 8 times greater than the odds of success when either of its corresponding PCP or PE tasks was implemented individually.

10.5 SUMMARY OF THE RANKED TASK STRINGS

For the purpose of determining the ranking of task strings, a correlation analysis identified 55 task strings for cost success and 12 task strings for schedule success. Subsequently, these task strings were investigated to identify the leveraged effects on cost and schedule success as opposed to either PCP or PE tasks. Based on the results of the leveraged effects, these task strings were further divided into three groups: (1) basic task string, (2) better task string, and (3) best task string. The results of the analysis identified 186 basic task strings, 48 better task strings, and 5 best task strings for cost success. As for schedule success, 233 basic task strings, 5 better task strings, and 1 best task strings were also identified. The results of the ranked task strings are summarized below in Table 10.7.

Project Success	# of Basic TS	# of Better TS	# of Best TS
Cost Success	186	48	5
Schedule Success	233	5	1

Table 10.7: Summary of Basic/Better/Best Task Strings.

Best task strings are the PCP/PE continuous task strings that have a significantly positive association with project success and also have significant leveraged effects as opposed to both PCP and PE tasks. These include 5 task strings for cost success and 1 task string for schedule success. These best task strings are specifically described below in Tables 10.7-8.

Task String #	PCP/PE Task	Task String Description
5	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE2	Setup storage trailer and lay down area
56	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
	PE17	Review bid documents for materials and vendors and any vendor responsibilities
171	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
	PE58	Identify work that impacts electrical activity
210	PCP38	Customize the computerized tracking & control system for the current project
	PE68	Compare the project costs to the budget
231	PCP38	Customize the computerized tracking & control system for the current project
	PE78	Ensure labor hours are turned in

Table 10.7: Summary of Best Task Strings for Cost Success.

Task String #	PCP/PE Task	Task String Description
126	PCP7	Review plans, specifications, and schedule (Field supervisor)
	PE33	Determine the subcontractors' schedule

Table 10.8: Summary of Best Task Strings for Schedule Success.

Better task strings are the PCP/PE continuous task strings that have a significantly positive association with project success and also have significant leveraged effects as opposed to either PCP or PE tasks. These include 48 task strings for cost success and 5 task strings for schedule success. These better task strings are presented in Table 10.9-10.

Task String #	PCP/PE Task	Task String Description
1	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE1	Setup office trailer in a timely manner and in a convenient location
2	PCP7	Review plans, specifications, and schedule (Field supervisor)
	PE1	Setup office trailer in a timely manner and in a convenient location
8	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
	PE2	Setup storage trailer and lay down area
9	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE2	Setup storage trailer and lay down area
14	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE7	Make sure the foreman has everything he or she needs to get started
24	PCP30	Develop installation sequence and layout drawings
	PE8	Make use of a project file
31	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE10	Use an RFI tracking and processing system
34	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE10	Use an RFI tracking and processing system
36	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE10	Use an RFI tracking and processing system
47	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE12	Keep all schedule documentation, including delays
50	PCP30	Develop installation sequence and layout drawings
	PE12	Keep all schedule documentation, including delays
52	PCP2	Hold turnover meeting between estimator and project manager
	PE17	Review bid documents for materials and vendors and any vendor responsibilities
59	PCP30	Develop installation sequence and layout drawings
	PE17	Review bid documents for materials and vendors and any vendor responsibilities
73	PCP30	Develop installation sequence and layout drawings
	PE22	Ensure good material handling on site
75	PCP38	Customize the computerized tracking & control system for the current project
	PE22	Ensure good material handling on site
76	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE23	Communicate all material information to field
77	PCP7	Review plans, specifications, and schedule (Field supervisor)
	PE23	Communicate all material information to field
78	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE23	Communicate all material information to field

Table 10.9: Summary of Better Task Strings for Cost Success.

Task String #	PCP/PE Task	Task String Description
80	PCP30	Develop installation sequence and layout drawings
	PE23	Communicate all material information to field
100	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE29	Schedule deliveries and pickups
101	PCP30	Develop installation sequence and layout drawings
	PE29	Schedule deliveries and pickups
103	PCP38	Customize the computerized tracking & control system for the current project
	PE29	Schedule deliveries and pickups
162	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE57	Review the schedule and identify milestone dates
164	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE57	Review the schedule and identify milestone dates
166	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE57	Review the schedule and identify milestone dates
167	PCP38	Customize the computerized tracking & control system for the current project
	PE57	Review the schedule and identify milestone dates
173	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE58	Identify work that impacts electrical activity
177	PCP30	Develop installation sequence and layout drawings
	PE60	Review the schedule with the field
178	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE60	Review the schedule with the field
183	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE61	Update the schedule regularly
191	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE64	Track labor costs
192	PCP12	Prepare construction takeoff
	PE64	Track labor costs
193	PCP27	Develop, review, or expand cost code scheme
	PE64	Track labor costs
194	PCP38	Customize the computerized tracking & control system for the current project
	PE64	Track labor costs
197	PCP12	Prepare construction takeoff
	PE65	Track material and subcontractor costs
199	PCP38	Customize the computerized tracking & control system for the current project
	PE65	Track material and subcontractor costs

Table 10.9: Summary of Better Task Strings for Cost Success (Continued).

Task String #	PCP/PE Task	Task String Description
207	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE68	Compare the project costs to the budget
208	PCP12	Prepare construction takeoff
	PE68	Compare the project costs to the budget
209	PCP27	Develop, review, or expand cost code scheme
	PE68	Compare the project costs to the budget
211	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE72	Make sure that the field is aware of the quality needed
212	PCP7	Review plans, specifications, and schedule (Field supervisor)
	PE72	Make sure that the field is aware of the quality needed
214	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE72	Make sure that the field is aware of the quality needed
224	PCP9	Conduct site visit
	PE77	Maintain the correct crew mix and manpower level
225	PCP10	Compare estimated (bid) work activities & materials to planned performance
	PE77	Maintain the correct crew mix and manpower level
227	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE77	Maintain the correct crew mix and manpower level
228	PCP38	Customize the computerized tracking & control system for the current project
	PE77	Maintain the correct crew mix and manpower level
236	PCP3	Hold separate turnover meeting between project manager and field supervisor
	PE82	Ensure that all change orders and purchase orders are closed

Table 10.9: Summary of Better Task Strings for Cost Success (Continued).

Task String #	PCP/PE Task	Task String Description
24	PCP30	Develop installation sequence and layout drawings
	PE8	Make use of a project file
74	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE22	Ensure good material handling on site
106	PCP7	Review plans, specifications, and schedule (Field supervisor)
	PE31	Review the scope and determine the subcontractors' scope of work
107	PCP9	Conduct site visit
	PE31	Review the scope and determine the subcontractors' scope of work
123	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE32	Establish subcontracts

Table 10.10: Summary of Better Task Strings for Schedule Success.

Basic task strings are the PCP/PE continuous task strings that may have a significantly positive association with project success, but do not have significant leveraged effects as opposed to either PCP or PE tasks. These include 186 task strings for cost success and 233 task strings for schedule success. Table 10.11-12 summarizes some of basic task strings that have a significantly positive association with cost and schedule success. The rest of basic task strings that have no significant association with project success consists 184 task strings for cost success and 227 task strings for schedule success.

Task String #	PCP/PE Task	Task String Description
4	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
	PE1	Setup office trailer in a timely manner and in a convenient location
35	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
	PE10	Use an RFI tracking and processing system

Table 10.11: Summary of Basic Task Strings for Cost Success.

Task String #	PCP/PE Task	Task String Description
52	PCP2	Hold turnover meeting between estimator and project manager
	PE17	Review bid documents for materials and vendors and any vendor responsibilities
59	PCP30	Develop installation sequence and layout drawings
	PE17	Review bid documents for materials and vendors and any vendor responsibilities
102	PCP31	Develop field instructions, including panel, pull, or conduit schedules
	PE29	Schedule deliveries and pickups
112	PCP30	Develop installation sequence and layout drawings
	PE31	Review the scope and determine the subcontractors' scope of work
190	PCP2	Hold turnover meeting between estimator and project manager
	PE64	Track labor costs
230	PCP9	Conduct site visit
	PE78	Ensure labor hours are turned in

Table 10.12: Summary of Basic Task Strings for Schedule Success.

Chapter 11: Validation of the Effect of Task Strings

11.1 INTRODUCTION

This chapter attempts to validate task strings that contribute to project success. For this purpose, the effects of task string implementation on project success were investigated in terms of cost and schedule performance. The validation confirms which task strings contribute to project success. As a result, a list of the validated high-value task strings is presented with description of each.

11.2 VALIDATION OF THE EFFECTS OF TS IMPLEMENTATION

The basic concept of the validation is to confirm that high task string implementation contributes to project success. For the purpose of the validation, 50 sets of electrical projects were split into two groups: successful projects and unsuccessful projects. Of the 50 electrical projects, 30 were classified as successful in cost, and 42 in schedule. Then, the effect of task string implementation on project success was assessed to identify which task strings are of value. To identify which task strings are of value, the following four hypotheses were developed:

- H_1: Task strings are critical to project success when they are frequently implemented in successful projects.
- H_2: Task strings are less critical to project success when they are less frequently implemented in successful projects.
- H_3: Task strings do not contribute to project success when they are frequently implemented in unsuccessful projects.
- H_4: Task strings are needed for project success when they are less frequently implemented in unsuccessful projects.

Hypothesis H_1 and H_4 confirm that certain task strings contribute to project success. On the other hand, H_2 and H_3 show that some task strings do not contribute to project success. Therefore, the effects of task strings are validated if the task strings are frequently implemented in successful projects and at the same time are less frequently implemented in unsuccessful projects; otherwise, they fail to be validated. Figure 11.1 illustrates the basic idea of the validation process.

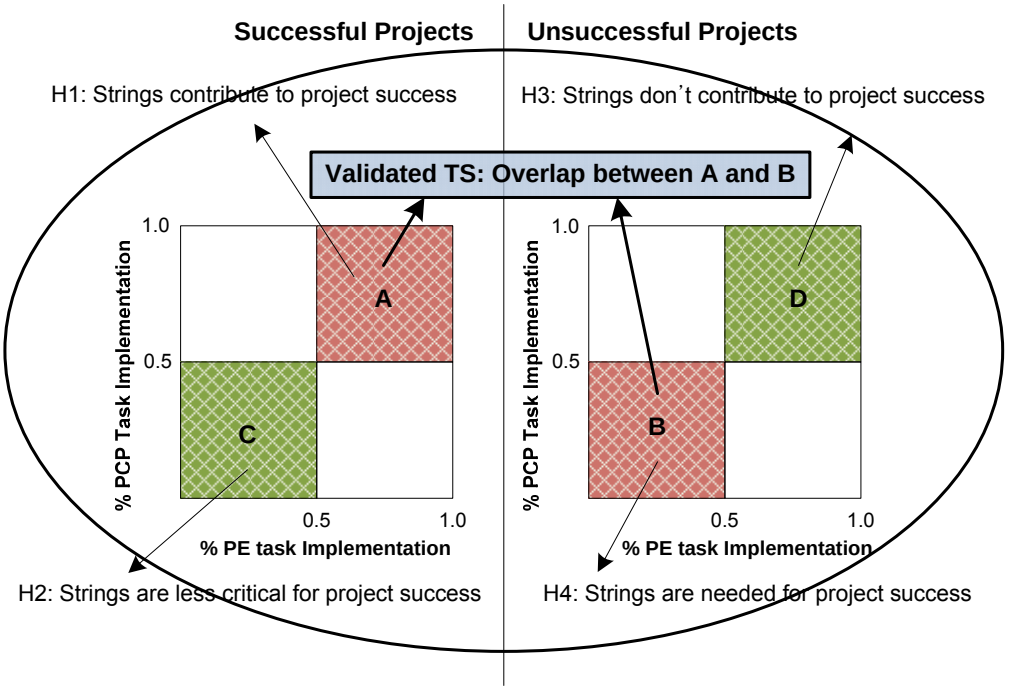

Figure 11.1: Validation of the Effects of Task String Implementation.

As shown in Figure 11.1, task strings that were implemented in more than 50% of successful projects (A) and were also implemented in less than 50% of unsuccessful projects (B) are confirmed as contributing to project success. On the other hand, task strings that were implemented in less than 50% of successful projects (C) or were implemented in more than 50% of unsuccessful projects (D) are invalidated.

11.3 RESULTS OF VALIDATION OF TS IMPLEMENTATION

For the validation purposes, 239 task strings that ranked in basic/better/best task string category were analyzed in terms of cost and schedule performance. Based on the percent task string implementation in successful and unsuccessful projects, each task string was plotted to identify which categories they should be included. Figure 11.2 graphically shows the plots of each task string in successful and unsuccessful projects.

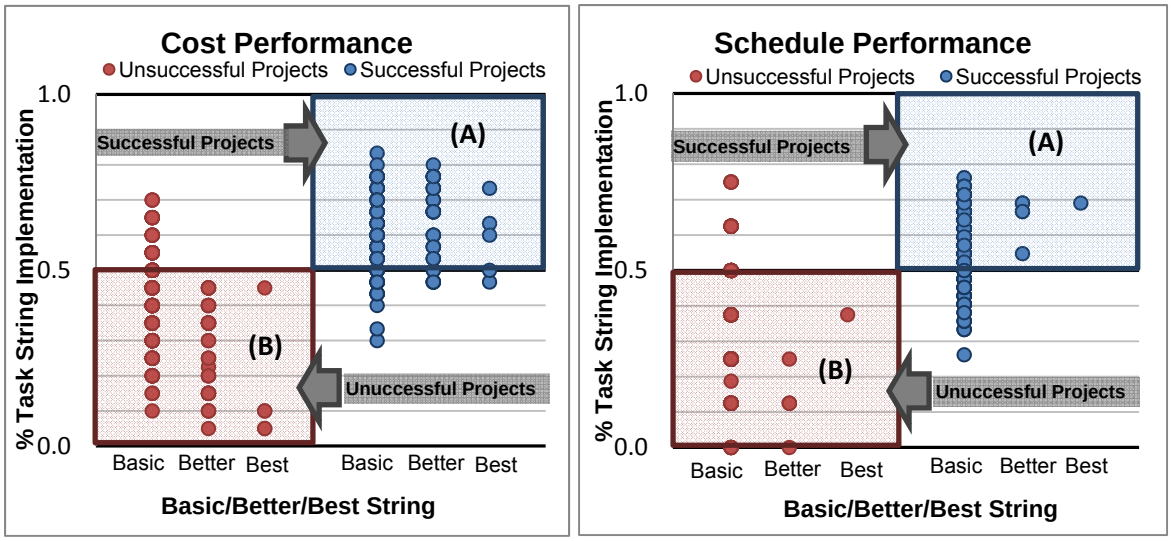

Figure 11.2: Scatter Plots of the Effects of TS Implementation.

Among the 239 task strings, the ones that are included in both A and B confirmed as task strings that contribute to project success. Therefore, 196 task strings were verified in terms of their effects on cost success and 145 task strings were verified in terms of their effects on schedule success. The results of the validation are described below in Table 11. 1.

Project Performance	Ranking of TS	# of Original TS	# of Validated TS	% of Validated TS
Cost Success	Basic	186	116	0.62
	Better	48	41	0.85
	Best	5	3	0.60
Schedule Success	Basic	233	133	0.57
	Better	5	5	1.00
	Best	1	1	1.00

Table 11.1: Summary of the Validation Results.

Overall, 66.9% of the ranked task strings were validated for cost success and 74.1% for schedule success. In particular, better task strings were verified more than other ranked strings, specifically 85.4% in cost success and 100% in schedule success. However, a relatively lower number of basic task strings was validated in terms of their contributions to project success, indicating 62.4% in cost success and 57.1% in schedule, respectively.

11.4 SUMMARY OF VALIDATION OF TS IMPLEMENTATION

During the validation, the effects of task strings were verified in terms of cost and schedule success. The results demonstrated that task strings are critical to project success in successful projects. As a result, it was confirmed that more than 67% of the task strings contribute to project success. A list of the validated high-value task strings (better/best strings) were summarized below in Table 11.2-10. The validated basic task strings were listed in Appendix F.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Best	5	3	Hold separate turnover meeting between project manager and field supervisor	2	Setup storage trailer and lay down area
Best	56	11	Identify value engineering and prefabrication opportunities and how to simplify the work	17	Review bid documents for materials and vendors and any vendor responsibilities
Best	171	11	Identify value engineering and prefabrication opportunities and how to simplify the work	58	Identify work that impacts electrical activity

Table 11.2: Summary of the Validated Best Strings for Cost.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Better	1	3	Hold separate turnover meeting between project manager and field supervisor	1	Setup office trailer in a timely manner and in a convenient location
Better	2	7	Review plans, specifications, and schedule (Field supervisor)	1	Setup office trailer in a timely manner and in a convenient location
Better	8	11	Identify value engineering and prefabrication opportunities and how to simplify the work	2	Setup storage trailer and lay down area
Better	9	31	Develop field instructions, including panel, pull, or conduit schedules	2	Setup storage trailer and lay down area
Better	14	10	Compare estimated (bid) work activities & materials to planned performance	7	Make sure the foreman has everything he or she needs to get started
Better	24	30	Develop installation sequence and layout drawings	8	Make use of a project file
Better	31	3	Hold separate turnover meeting between project manager and field supervisor	10	Use an RFI tracking and processing system
Better	34	10	Compare estimated (bid) work activities & materials to planned performance	10	Use an RFI tracking and processing system
Better	36	31	Develop field instructions, including panel, pull, or conduit schedules	10	Use an RFI tracking and processing system
Better	47	3	Hold separate turnover meeting between project manager and field supervisor	12	Keep all schedule documentation, including delays
Better	50	30	Develop installation sequence and layout drawings	12	Keep all schedule documentation, including delays

Table 11.3: Summary of the Validated Better Strings for Cost.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Better	73	30	Develop installation sequence and layout drawings	22	Ensure good material handling on site
Better	75	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	22	Ensure good material handling on site
Better	76	3	Hold separate turnover meeting between project manager and field supervisor	23	Communicate all material information to field
Better	77	7	Review plans, specifications, and schedule (Field supervisor)	23	Communicate all material information to field
Better	78	10	Compare estimated (bid) work activities & materials to planned performance	23	Communicate all material information to field
Better	80	30	Develop installation sequence and layout drawings	23	Communicate all material information to field
Better	100	10	Compare estimated (bid) work activities & materials to planned performance	29	Schedule deliveries and pickups
Better	101	30	Develop installation sequence and layout drawings	29	Schedule deliveries and pickups
Better	103	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	29	Schedule deliveries and pickups
Better	162	3	Hold separate turnover meeting between project manager and field supervisor	57	Review the schedule and identify milestone dates
Better	166	31	Develop field instructions, including panel, pull, or conduit schedules	57	Review the schedule and identify milestone dates
Better	173	31	Develop field instructions, including panel, pull, or conduit schedules	58	Identify work that impacts electrical activity
Better	177	30	Develop installation sequence and layout drawings	60	Review the schedule with the field
Better	178	31	Develop field instructions, including panel, pull, or conduit schedules	60	Review the schedule with the field
Better	183	31	Develop field instructions, including panel, pull, or conduit schedules	61	Update the schedule regularly
Better	191	10	Compare estimated (bid) work activities & materials to planned performance	64	Track labor costs
Better	192	12	Prepare construction takeoff	64	Track labor costs
Better	193	27	Develop, review, or expand cost code scheme	64	Track labor costs
Better	194	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	64	Track labor costs
Better	197	12	Prepare construction takeoff	65	Track material and subcontractor costs
Better	199	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	65	Track material and subcontractor costs

Table 11.4: Summary of the Validated Better Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Better	211	3	Hold separate turnover meeting between project manager and field supervisor	72	Make sure that the field is aware of the quality needed
Better	212	7	Review plans, specifications, and schedule (Field supervisor)	72	Make sure that the field is aware of the quality needed
Better	214	31	Develop field instructions, including panel, pull, or conduit schedules	72	Make sure that the field is aware of the quality needed
Better	224	9	Conduct site visit	77	Maintain the correct crew mix and manpower level
Better	225	10	Compare estimated (bid) work activities & materials to planned performance	77	Maintain the correct crew mix and manpower level
Better	227	31	Develop field instructions, including panel, pull, or conduit schedules	77	Maintain the correct crew mix and manpower level
Better	228	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	77	Maintain the correct crew mix and manpower level
Better	236	3	Hold separate turnover meeting between project manager and field supervisor	82	Ensure that all change orders and purchase orders are closed

Table 11.4: Summary of the Validated Better Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Best	126	7	Review plans, specifications, and schedule (Field supervisor)	33	Determine the subcontractors' schedule

Table 11.5: Summary of the Validated Best Strings for Schedule.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Better	24	30	Develop installation sequence and layout drawings	8	Make use of a project file
Better	74	31	Develop field instructions, including panel, pull, or conduit schedules	22	Ensure good material handling on site
Better	106	7	Review plans, specifications, and schedule (Field supervisor)	31	Review the scope and determine the subcontractors' scope of work
Better	107	9	Conduct site visit	31	Review the scope and determine the subcontractors' scope of work
Better	123	31	Develop field instructions, including panel, pull, or conduit schedules	32	Establish subcontracts

Table 11.6: Summary of the Validated Better Strings for Schedule.

Chapter 12: Conclusions and Recommendations

12.1 INTRODUCTION

This research established task-level strategies for project success improvement by stringing together planning and execution tasks. During the research, a series of studies were conducted to achieve the primary goals, including pre-screening, model development, data collection, data analysis, and discussions of the results. This chapter summarized the findings of the research and also provided evidence to support hypotheses set forth in previous chapters. Based on the findings, future studies were also suggested beyond the scope of the current research. Hence, this chapter attempted to provide additional opportunities for expanding the current research. In summary, several contributions were also made for practice as well as the project management body of knowledge.

12.2 CONCLUSIONS

The ultimate goal of the research is to achieve project performance improvement through effective task-level strategies. To obtain this goal, the research developed continuous task string models by stringing together pre-construction planning tasks and relevant project execution tasks. The research also demonstrated the effects of continuous task strings on project performance in terms of cost, and schedule success. Moreover, the research attempted to provide evidence to support four main hypotheses set forth in chapter 7. The specific evidence for hypotheses is presented below.

- *Hypothesis I: PCP tasks are needed for successful implementation of PE tasks.*

This study identified which PCP tasks are needed for successful implementation of PE tasks. The hypothesis was tested based on the results of experts' assessment. As a result, 239 continuous task strings that pair PCP tasks with relevant PE tasks were identified. This study indicated that PCP tasks are implemented for successful implementation of PE tasks.

- *Hypothesis II-(a): Levels of some task string usage are positively associated with project success.*

This study provided empirical evidence that supports the expectation that higher levels of selected task string implementation produce significant benefits. The results of this study indicated that levels of some task string implementation are critical to achieving project cost and schedule success. Most of the task string groups are significantly different in cost success for successful projects and unsuccessful projects at the 95% confidence level. The significant task string groups for cost success include mobilization, document management, tool management, communication, scheduling, cost control and billing, quality management, labor management, and project closeout. As for schedule success, the tool management group showed a significant difference between the two groups at the 95% confidence level. In addition, the tool management and safety management groups may contribute to schedule success, even though they only indicated a significant difference at the 90% confidence level.

- *Hypothesis II-(b): Implementation of task strings significantly improves the likelihood of achieving successful outcomes, as opposed to implementing either PCP or PE tasks individually and not in conjunction with their related tasks.*

This study investigated the leveraged effect of task strings on project success to identify significant task string groups that have greater cost success than PCP or PE tasks– only at the 95% confidence level. As a result, task strings had greater cost success than both PCP and PE tasks for the task string groups of material management, subcontractor management, and cost control and billing. As for schedule success, the material management, subcontractor management, scheduling, and cost control and billing task string groups achieved a greater schedule success with task strings than with both PCP and PE tasks.

- *Hypothesis III: The impact of each task string on project performance varies based on the nature of task strings.*

This study focused on determining the high-value task strings that contribute to project success in terms of cost and schedule. To identify the high-value task strings, task strings were divided into Basic/Better/Best strings according to their leveraged effects as opposed to implementing either PCP or PE tasks individually. The results of the analysis identified 186 Basic task strings, 48 Better task strings, and 5 Best task strings for cost success. As for schedule success, 233 Basic task strings, 5 Better task strings, and 1 Best task string were also identified. As a result, 53 high-value task strings for cost success and 6 high-value task strings for schedule success were identified.

These studies demonstrated the importance of task string implementation in electrical projects to achieve significant project success improvement. As a consequence, task strings are a powerful strategy for increasing the project success rate on electrical projects. Furthermore, the research provided the high-value task strings, including a list of corresponding pre-construction planning and project execution tasks for an effective

project management strategy. These high-value task strings may contribute to project performance improvement. Among them, the validated best task strings for cost and schedule success are specifically described below in Tables 12.1-2.

Project Success	TS #	PCP/PE Task	Task String Description
Cost Success	5	PCP3	Hold separate turnover meeting between project manager and field supervisor
		PE2	Setup storage trailer and lay down area
	56	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
		PE17	Review bid documents for materials and vendors and any vendor responsibilities
	171	PCP11	Identify value engineering and prefabrication opportunities and how to simplify the work
		PE58	Identify work that impacts electrical activity
Schedule Success	126	PCP7	Review plans, specifications, and schedule (Field supervisor)
		PE33	Determine the subcontractors' schedule

Table 12.1: The Validated Best Task Strings for Cost and Schedule Success.

12.3 RECOMMENDATIONS

Based on these findings, future studies are suggested beyond the scope of the current research. Hence, this chapter attempts to provide additional opportunities for expanding the current research. This task string study was conducted with moderately implemented tasks, including 11 PCP and 47 PE tasks. However, the tasks in other task groups that were excluded in this study can be further studied when more data are available. Therefore, more electrical project data should be collected to expand the task string models. In addition to expanding task string models, the following future studies are also recommended:

- *Study 1: The Influence of Task Strings by Project Characteristics on Project Performance.*

The purpose of this study would be to identify the critical task strings that have a significant effect on specific project characteristics. This study would suggest strategic implementation of critical task strings for electrical contractors to achieve project success improvement given the characteristics of projects. The results of the study would provide electrical contractors with strategic guidelines that contain critical task strings for the specific characteristics of the projects.

- *Study 2: A Comprehensive Influence Model for Effective Project Management.*

The primary purpose of this study would be to develop a quantitative model of the relationship between project characteristics, planning, execution, and performance. This model would be used to predict the probability of project success considering the relative impact of each factor on performance. As a result, this model would provide the degree to which factors have an influence on project performance. This consequently would determine the relative importance of each factor.

12.4 CONTRIBUTIONS

The ultimate goal of the research was to help electrical contractors to achieve project performance improvement by stringing together planning and execution tasks. The research overall makes several contributions to practice as well as the project management body of knowledge. These contributions may extend to mechanical and

plumbing contractors because these trades are basically performing very similar planning and execution tasks. These contributions include:

Contributions to Practice

- Allows electrical contractors to understand the relationships between pre-construction planning and project execution tasks.
- Aids electrical contractors in achieving significantly better performance by implementing continuous task strings that have been proven to be specifically effective at improving cost, and schedule success.

Contributions to the Project Management Body of Knowledge

- Builds a theoretical foundation that identifies the relationships between PCP and PE tasks by stringing together relevant tasks.
- Quantified the effects of continuous task strings on project performance in terms of cost and schedule success.

SECTION IV: APPENDICES

Appendix A: Six Task Groups (Excluded in This Study)

A.1 TASK GROUP (A)

32-PCP Tasks

Task #	Pre-Construction Planning Tasks
1	Finalize selection of project manager, field supervisor, and other key team members
4	Hold pre-job (planning) kickoff meeting with internal team members to assign responsibilities
5	Review contract for unfavorable or high risk clauses
6	Project manager reviews plans, specifications, and schedule
8	Create a list of issues that need to be resolved and begin the request for information (RFI) process
13	Set up project files and create contact list
14	Set up computerized tracking and control system (forms, database, schedule, tracking)
15	Initiate a change management system
16	Initiate a request for information (RFI) tracking and processing system
17	Initiate a submittal tracking and processing system
19	Review subcontractor/supplier/vendor prices and qualifications
20	Negotiate pricing & contract conditions and select subcontractors/suppliers/vendors
21	Develop and issue purchase orders and contracts for materials and equipment
22	Order long-lead-time materials and equipment
23	Request submittals, cut sheets, and shop drawings
24	Develop and process log and book of submittals, cut sheets, and shop drawings
25	Develop material delivery and handling plan
26	Develop material storage and staging plan
28	Develop budget by breaking down labor, material, overhead, and profit costs
29	Develop schedule of values
33	Review customer's schedule and timeline
34	Identify work that impacts electrical activities
35	Review the work sequence and long-lead-time material/equipment delivery dates
36	Coordinate electrical schedule with the customer's schedule
39	Develop labor and materials tracking report
40	Review meeting schedule
41	Review request for information (RFI) process
42	Review change order process and field change management process
43	Review submittal processing procedure
44	Review billing and invoicing procedures
45	Review project and field reporting and tracking procedures
46	Review electrical and customer schedules

Table A.1.1: Summary of PCP tasks in Task Group (A).

16-PE Tasks

Task #	Project Execution Tasks
3	Setup communication system
4	Secure access to site
5	Bring in needed labor, tools and material to get started
14	Use a submittal tracking and processing system
18	Develop and issue purchase orders for materials
20	Request submittals, cutsheets and shop drawings from vendors
21	Document purchase orders
38	*Onsite General safety
41	Ensure that safety log is update and all incidents are documented
51	Submit change order requests and cost proposals
53	Document change orders and incorporate them into the budget
55	Purchase materials or subcontractors and inform the field
69	Use the schedule of values
70	Bill your costs on time
83	Receive final payment and retainage
85	Demobilize

Table A.1.2: Summary of PE tasks in Task Group (A).

A.2 TASK GROUP (B)

32-PCP Tasks

Task #	Pre-Construction Planning Tasks
1	Finalize selection of project manager, field supervisor, and other key team members
4	Hold pre-job (planning) kickoff meeting with internal team members to assign responsibilities
5	Review contract for unfavorable or high risk clauses
6	Project manager reviews plans, specifications, and schedule
8	Create a list of issues that need to be resolved and begin the request for information (RFI) process
13	Set up project files and create contact list
14	Set up computerized tracking and control system (forms, database, schedule, tracking)
15	Initiate a change management system
16	Initiate a request for information (RFI) tracking and processing system
17	Initiate a submittal tracking and processing system
19	Review subcontractor/supplier/vendor prices and qualifications
20	Negotiate pricing & contract conditions and select subcontractors/suppliers/vendors
21	Develop and issue purchase orders and contracts for materials and equipment
22	Order long-lead-time materials and equipment
23	Request submittals, cut sheets, and shop drawings
24	Develop and process log and book of submittals, cut sheets, and shop drawings
25	Develop material delivery and handling plan
26	Develop material storage and staging plan
28	Develop budget by breaking down labor, material, overhead, and profit costs
29	Develop schedule of values
33	Review customer's schedule and timeline
34	Identify work that impacts electrical activities
35	Review the work sequence and long-lead-time material/equipment delivery dates
36	Coordinate electrical schedule with the customer's schedule
39	Develop labor and materials tracking report
40	Review meeting schedule
41	Review request for information (RFI) process
42	Review change order process and field change management process
43	Review submittal processing procedure
44	Review billing and invoicing procedures
45	Review project and field reporting and tracking procedures
46	Review electrical and customer schedules

Table A.2.1: Summary of PCP task in Task Group (B).

47-PE Tasks

Task #	Project Execution Task
1	Setup office trailer in a timely manner and in a convenient location
2	Setup storage trailer and lay down area in a convenient location
7	Make sure the foreman has everything he or she needs to get started with the work
8	Develop and implement a project file system
9	Implement a documentation control system
10	Implement an RFI tracking and processing system
11	Implement a change order tracking and processing system
12	Keep a record of all schedules and updates including delays
17	Review bid docs to verify required materials and identify potential vendors & any vendor responsibilities
19	Establish delivery dates for materials and equipment
22	Implement an effective material handling system on site
23	Communicate all material information to field personnel
25	Lock in the pricing for materials and equipment
27	Reconcile the invoice with the estimated material costs
28	Review contract drawing, specifications, and the bid to identify and purchase special tools
29	Schedule regular delivery and pickup of tools
31	Review the scope and document the subcontractors' scope of work
32	Implement subcontracts
33	Determine the subcontractors' schedule based on input from the subcontractors
34	Request submittals and shop drawings from the subcontractors
35	Provide Information to the site supervisor and foreman about the subcontractors and the point of contact
37	Make sure the subcontractors are licensed and are qualified to do the job
39	Identify safety concerns associated with specific job activities
40	Identify and purchase additional safety equipment as needed
42	Perform job walks regularly to ensure that the safety procedures are being followed
43	Keep the CEO/VP informed of progress and involved with the project through reports, meetings, etc.
44	Implement procedures to communicate frequently with the foreman, especially to solve problems
45	Implement procedures to communicate frequently with vendors and subcontractors
46	Implement procedures to communicate frequently with the General Contractor and Owner
54	Track change orders separately from the original scope
57	Review the schedule regularly and identify milestone dates that must be met
58	Identify work that impacts electrical activity
60	Review the schedule routinely with field personnel to ensure all parties understand the milestones
61	Update the schedule regularly to track progress
63	Use cost codes (Cost breakdown) to account for activities
64	Track labor costs and compare actual costs to estimated costs
65	Track material and subcontractors costs and compare actual costs to estimated costs
66	Once issued change orders have been approved, include them in the billing process
68	Compare the actual project costs to the budget to track progress
72	Clarify quality requirements for field personnel
73	Check and document the quality of installation through site visits
74	Develop and implement commissioning and testing procedures
77	Identify and maintain the correct crew mix and manpower level
78	Ensure labor hours are turned in by workers in a timely manner
79	Ensure that all punchlist items are completed and signed off in a timely manner
82	Ensure that all change orders and purchase orders are closed before job completion
84	Turn all project closeout documents over to the General Contractor

Table A.2.2: Summary of PE tasks in Task Group (B).

A.3 TASK GROUP (C)

11-PCP Tasks

Task #	Pre-Construction Planning Tasks
2	Hold turnover meeting between estimator and project manager
3	Hold separate turnover meeting between project manager and field supervisor
7	Field supervisor reviews plans, specifications, and schedule
9	Conduct site visit
10	Compare estimated (bid) work activities & materials to planned performance
11	Identify value engineering and prefabrication opportunities and how to simplify the work
12	Prepare construction takeoff
27	Develop, review, or expand cost code scheme
30	Develop installation sequence and layout drawings
31	Develop field instructions, including panel, pull, or conduit schedules
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project

Table A.3.1: Summary of PCP tasks in Task Group (C).

16-PE Tasks

Task #	Project Execution Tasks
3	Setup communication system
4	Secure access to site
5	Bring in needed labor, tools and material to get started
14	Use a submittal tracking and processing system
18	Develop and issue purchase orders for materials
20	Request submittals, cutsheets and shop drawings from vendors
21	Document purchase orders
38	*Onsite General safety
41	Ensure that safety log is update and all incidents are documented
51	Submit change order requests and cost proposals
53	Document change orders and incorporate them into the budget
55	Purchase materials or subcontractors and inform the field
69	Use the schedule of values
70	Bill your costs on time
83	Receive final payment and retainage
85	Demobilize

Table A.3.2: Summary of PE tasks in Task Group (C).

A.4 TASK GROUP (E)

43-PCP Tasks

#	Pre-Construction Planning Task
1	Finalize selection of project manager, field supervisor, and other key team members
2	Hold turnover meeting between estimator and project manager
3	Hold separate turnover meeting between project manager and field supervisor
4	Hold pre-job (planning) kickoff meeting with internal team members to assign responsibilities
5	Review contract for unfavorable or high risk clauses
6	Review plans, specifications, and schedule (Project manager)
7	Review plans, specifications, and schedule (Field supervisor)
8	Create a list of issues that need to be resolved and begin the request for information (RFI) process
9	Conduct site visit
10	Compare estimated (bid) work activities & materials to planned performance
11	Identify value engineering and prefabrication opportunities and how to simplify the work
12	Prepare construction takeoff
13	Set up project files and create contact list
14	Set up computerized tracking and control system (forms, database, schedule, tracking)
15	Initiate a change management system
16	Initiate a request for information (RFI) tracking and processing system
17	Initiate a submittal tracking and processing system
19	Review subcontractor/supplier/vendor prices and qualifications
20	Negotiate pricing & contract conditions and select subcontractors/suppliers/vendors
21	Develop and issue purchase orders and contracts for materials and equipment
22	Order long-lead-time materials and equipment
23	Request submittals, cut sheets, and shop drawings
24	Develop and process log and book of submittals, cut sheets, and shop drawings
25	Develop material delivery and handling plan
26	Develop material storage and staging plan
27	Develop, review, or expand cost code scheme
28	Develop budget by breaking down labor, material, overhead, and profit costs
29	Develop schedule of values
30	Develop installation sequence and layout drawings
31	Develop field instructions, including panel, pull, or conduit schedules
33	Review customer's schedule and timeline
34	Identify work that impacts electrical activities
35	Review the work sequence and long-lead-time material/equipment delivery dates
36	Coordinate electrical schedule with the customer's schedule
38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project
39	Develop labor and materials tracking report
40	Review meeting schedule
41	Review request for information (RFI) process
42	Review change order process and field change management process
43	Review submittal processing procedure
44	Review billing and invoicing procedures
45	Review project and field reporting and tracking procedures
46	Review electrical and customer schedules

Table A.4.1: Summary of PCP tasks in Task Group (E).

22-PE Tasks

Task #	Project Execution Tasks
6	Walk through the jobsite
13	Update as-built drawings
15	Use internal prefabrication drawings
16	Keep records of meeting minutes
24	Check material packaging, labels and status onsite
26	Schedule material delivery using staged releases to the site depending on phases
30	Track tool usage
36	Schedule onsite visit and walkthrough the jobsite with the subcontractors
47	Attend jobsite meetings and coordinate with other trades
48	Visit the site regularly
49	Review and understand the scope
50	Identify problems with the drawings and specifications
52	Schedule meetings to discuss change issues
56	Suggest alternate processes or materials that enhance value engineering on the jobsite
59	Give input about the schedule to the General Contractor
62	Review or establish look-ahead scheduling process
67	Use the project percentage complete data
71	Use a pre-bill process
75	Use a pre-punchlist
76	Effectively use prefabrication
80	Review specifications for project closeout
81	Use a project closeout checklist

Table A.4.2: Summary of PE tasks in Task Group (E).

A.5 TASK GROUP (F)

3-PCP Tasks

Task #	Pre-Construction Planning Tasks
18	Develop a "Labor Requirements/Expectations" letter
32	Develop prefabrication drawings for field use (when applicable)
37	Create a bar chart schedule

Table A.5.1: Summary of PCP tasks in Task Group (F).

63-PE Tasks

#	Project Execution Tasks
1	Setup office trailer in a timely manner and in a convenient location
2	Setup storage trailer and lay down area
3	Setup communication system
4	Secure access to site
5	Bring in needed labor, tools, and material to get started
7	Make sure the foreman has everything he or she needs to get started
8	Make use of a project file
9	Use a documentation control system
10	Use an RFI tracking and processing system
11	Use a change order tracking and processing system
12	Keep all schedule documentation, including delays
14	Use a submittal tracking and processing system
17	Review bid documents for materials and vendors and any vendor responsibilities
18	Develop and issue purchase orders for materials
19	Establish delivery dates
20	Request submittals, cut sheets, and shop drawings from vendors
21	Document purchase orders
22	Ensure good material handling on site
23	Communicate all material information to field
25	Lock in the needed prices
27	Make sure the invoice matches the material costs
28	Review contract drawing, specifications, and the bid for any special needs
29	Schedule deliveries and pickups

Table A.5.2: Summary of PE tasks in Task Group (F).

#	Project Execution Tasks
31	Review the scope and determine the subcontractors' scope of work
32	Establish subcontracts
33	Determine the subcontractors' schedules
34	Request submittals and shop drawings
35	Inform the field about the subcontractors and the people to contact
37	Make sure the subcontractors are licensed and are capable of doing the job
38	Ensure on-site general safety
39	Identify safety issues with the existing job and specific job activities
40	Plan for any additional needs for safety equipment
41	Ensure that safety log is updated and all incidents are documented
42	Perform job walks to ensure that the safety rules are being followed
43	Receive support from the company CEO/VP
44	Communicate constantly with the foreman, especially when problems occur
45	Communicate constantly with the vendors and subcontractors
46	Communicate constantly with the General Contractor and Owner
51	Submit change order requests and cost proposals
53	Document change orders and incorporate them into the budget
54	Track change orders
55	Purchase materials or hire subcontractors and inform the field
57	Review the schedule and identify milestone dates
58	Identify work that impacts electrical activity
60	Review the schedule with the field
61	Update the schedule regularly
63	Use cost codes (Cost breakdown)
64	Track labor costs
65	Track material and subcontractor costs
66	Include issued change orders
68	Compare the project costs to the budget
69	Use the schedule of values
70	Bill your costs on time
72	Make sure that the field is aware of the quality needed
73	Check the quality of installation through site visits
74	Perform test results/commissioning
77	Maintain the correct crew mix and manpower level
78	Ensure labor hours are turned in
79	Ensure that all punch list items are signed off on
82	Ensure that all change orders and purchase orders are closed
83	Receive final payment and retainage
84	Turn all project closeout documents over to the General Contractor
85	Demobilize

Table A.5.2: Summary of PE tasks in Task Group (F) (Continued).

A.6 TASK GROUP (G)

3-PCP Tasks

Task #	Pre-Construction Planning Tasks
18	Develop a "Labor Requirements/Expectations" letter
32	Develop prefabrication drawings for field use (when applicable)
37	Create a bar chart schedule

Table A.6.1: Summary of PCP tasks in Task Group (G).

22-PE Tasks

Task #	Project Execution Tasks
6	Walk through the jobsite
13	Update as-built drawings
15	Use internal prefabrication drawings
16	Keep records of meeting minutes
24	Check material packaging, labels and status onsite
26	Schedule material delivery using staged releases to the site depending on phases
30	Track tool usage
36	Schedule onsite visit and walkthrough the jobsite with the subcontractors
47	Attend jobsite meetings and coordinate with other trades
48	Visit the site regularly
49	Review and understand the scope
50	Identify problems with the drawings and specifications
52	Schedule meetings to discuss change issues
56	Suggest alternate processes or materials that enhance value engineering on the jobsite
59	Give input about the schedule to the General Contractor
62	Review or establish look-ahead scheduling process
67	Use the project percentage complete data
71	Use a pre-bill process
75	Use a pre-punchlist
76	Effectively use prefabrication
80	Review specifications for project closeout
81	Use a project closeout checklist

Table A.6.2: Summary of PE tasks in Task Group (G).

Appendix B: The Questionnaire of the First-Round Survey

B.1 SURVEY INSTRUCTION

The purpose of this study is to investigate task-to-task continuities that pair pre-construction planning (PCP) tasks with project execution (PE) tasks for electrical contractors to achieve significantly better performance. In this survey, we are trying to identify tasks that you believe do or do not need to be performed during planning that set up the systems for managing the project following execution. During the survey, you are being asked to identify which pre-construction planning (PCP) tasks are needed to effectively implement the following project execution (PE) task. This opinion-based survey will take you about 15 minutes to complete. Please check the box in the left column if the PCP tasks need to be performed in order to effectively implement each of the PE task described below. If you think there are no PCP tasks that need to be completed in order to implement the PE task, check "None of the above".

B.2 SURVEY QUESTIONNAIRES

Segment I

1-1. PE Task 1: Setup office trailer in a timely manner and in a convenient location

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

1-2.PE Task 2: Setup storage trailer and lay down area in a convenient location

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

1-3. PE Task 7: Make sure the foreman has everything he or she needs to get started with the work

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

1-4. PE Task 8: Develop and implement a project file system

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit

- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

1-5. PE Task 9: Implement a documentation control system

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

1-6. PE Task 10: Implement an RFI tracking and processing system

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work

- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

1-7. PE Task 11: Implement a change order tracking and processing system

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

1-8. PE Task 12: Keep a record of all schedules and updates including delays

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff

- [ ] Develop, review, or expand cost code scheme
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

1-9. PE Task 17: Review bid docs to verify required materials and identify potential vendors & any vendor responsibilities

* Pre-Construction Planning Tasks are listed below

- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

1-10. PE Task 19: Establish delivery dates for materials and equipment

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

Segment II

2-1. PE Task 22: Implement an effective material handling system on site

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor

- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

2-2.PE Task 23: Communicate all material information to field personnel

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

2-3. PE Task 25: Lock in the pricing for materials and equipment

* Pre-Construction Planning Tasks are listed below

- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

2-4. PE Task 27: Reconcile the invoice with the estimated material costs

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance

- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

2-5. PE Task 28: Review contract drawing, specifications, and the bid to identify and purchase special tools

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

2-6. PE Task 29: Schedule regular delivery and pickup of tools

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

2-7. PE Task 31: Review the scope and document the subcontractors' scope of work

* Pre-Construction Planning Tasks are listed below

- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

2-8. PE Task 32: Implement subcontracts * Pre-Construction Planning Tasks are listed below

- ☐ Conduct site visit
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

2-9. PE Task 33: Determine the subcontractors' schedule based on input from the subcontractors

* Pre-Construction Planning Tasks are listed below

- ☐ Conduct site visit
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Develop, review, or expand cost code scheme
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

2-10. PE Task 34: Request submittals and shop drawings from the subcontractors

* Pre-Construction Planning Tasks are listed below

- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ None of the above

2-11. PE Task 35: Provide Information to the site supervisor and foreman about the subcontractors and the point of contact

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

2-12. PE Task 37: Make sure the subcontractors are licensed and are qualified to do the job

* Pre-Construction Planning Tasks are listed below

- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

2-13. PE Task 39: Identify safety concerns associated with specific job activities

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager

- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

Segment III

3-1. PE Task 40: Identify and purchase additional safety equipment as needed

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

3-2.PE Task 42: Perform job walks regularly to ensure that the safety procedures are being followed

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings

- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-3. PE Task 43: Keep the CEO/VP informed of progress and involved with the project through reports, meetings

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

3-4. PE Task 44: Implement procedures to communicate frequently with the foreman, especially to solve problems

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules

- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-5. PE Task 45: Implement procedures to communicate frequently with vendors and subcontractors

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-6. PE Task 46: Implement procedures to communicate frequently with the General Contractor and Owner

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules

- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-7. PE Task 54: Track change orders separately from the original scope

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

3-8. PE Task 57: Review the schedule regularly and identify milestone dates that must be met

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-9. PE Task 58: Identify work that impacts electrical activity

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Compare estimated (bid) work activities & materials to planned performance

- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Customize the computerized tracking & control system (database/schedule/etc) for the current project
- [ ] None of the above

3-10. PE Task 60: Review the schedule routinely with field personnel to ensure all parties understand the milestones * Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

3-11. PE Task 61: Update the schedule regularly to track progress

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] None of the above

3-12. PE Task 63: Use cost codes (Cost breakdown) to account for activities

* Pre-Construction Planning Tasks are listed below

- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

Segment VI

4-1. PE Task 64: Track labor costs and compare actual costs to estimated costs

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ None of the above

4-2.PE Task 65: Track material and subcontractors costs and compare actual costs to estimated costs

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule

- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

4-3. PE Task 66: Once issued change orders have been approved, include them in the billing process

* Pre-Construction Planning Tasks are listed below

- [ ] Hold turnover meeting between estimator and project manager
- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

4-4. PE Task 68: Compare the actual project costs to the budget to track progress

* Pre-Construction Planning Tasks are listed below

- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

4-5. PE Task 72: Clarify quality requirements for field personnel

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

4-6. PE Task 73: Check and document the quality of installation through site visits

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

4-7. PE Task 74: Develop and implement commissioning and testing procedures

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work

- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ Customize the computerized tracking & control system (database/schedule/etc) for the current project
- ☐ None of the above

4-8. PE Task 77: Identify and maintain the correct crew mix and manpower level

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Conduct site visit
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ None of the above

4-9. PE Task 78: Ensure labor hours are turned in by workers in a timely manner

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ None of the above

4-10. PE Task 79: Ensure that all punchlist items are completed and signed off in a timely manner

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ None of the above

4-11. PE Task 82: Ensure that all change orders and purchase orders are closed before job completion

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager
- ☐ Hold separate turnover meeting between project manager and field supervisor
- ☐ Field supervisor reviews plans, specifications, and schedule
- ☐ Conduct site visit
- ☐ Compare estimated (bid) work activities & materials to planned performance
- ☐ Identify value engineering and prefabrication opportunities and how to simplify the work
- ☐ Prepare construction takeoff
- ☐ Develop, review, or expand cost code scheme
- ☐ Develop installation sequence and layout drawings
- ☐ Develop field instructions, including panel, pull, or conduit schedules
- ☐ None of the above

4-12. PE Task 84: Turn all project closeout documents over to the General Contractor

* Pre-Construction Planning Tasks are listed below

- ☐ Hold turnover meeting between estimator and project manager

- [ ] Hold separate turnover meeting between project manager and field supervisor
- [ ] Field supervisor reviews plans, specifications, and schedule
- [ ] Conduct site visit
- [ ] Compare estimated (bid) work activities & materials to planned performance
- [ ] Identify value engineering and prefabrication opportunities and how to simplify the work
- [ ] Prepare construction takeoff
- [ ] Develop, review, or expand cost code scheme
- [ ] Develop installation sequence and layout drawings
- [ ] Develop field instructions, including panel, pull, or conduit schedules
- [ ] None of the above

Appendix C: The Results of the First-Round Survey

As a result of the first survey, 84 task strings were reclassified as continuous task strings. These are summarized below in Table C.1.1.

PCP#	PCP Task	PE#	PE Task	% of Selection by Experts)
11	Identify value engineering and prefabrication opportunities and how to simplify the work	1	Setup office trailer in a timely manner and in a convenient location	80.0
11	Identify value engineering and prefabrication opportunities and how to simplify the work	2	Setup storage trailer and lay down area in a convenient location	100.0
31	Develop field instructions, including panel, pull, or conduit schedules	2		80.0
2	Hold turnover meeting between estimator and project manager	7	Make sure the foreman has everything he or she needs to get started with the work	80.0
9	Conduct site visit	7		60.0
10	Compare estimated (bid) work activities & materials to planned performance	7		80.0
11	Identify value engineering and prefabrication opportunities and how to simplify the work	7		60.0
12	Prepare construction takeoff	7		80.0
3	Hold separate turnover meeting between project manager and field supervisor,	8	Develop and implement a project file system	80.0
7	Field supervisor reviews plans, specifications, and schedule	8		80.0
9	Conduct site visit	8		80.0
10	Compare estimated (bid) work activities & materials to planned performance	8		60.0
27	Develop, review, or expand cost code scheme	8		80.0
30	Develop installation sequence and layout drawings	8		100.0

Table C.1.1: Results of the First-Round Survey.

PCP#	PCP Task	PE#	PE Task	% of Selection by Experts)
3	Hold separate turnover meeting between project manager and field supervisor	9	Implement a documentation control system	80.0
7	Field supervisor reviews plans, specifications, and schedule	9		60.0
10	Compare estimated (bid) work activities & materials to planned performance	9		80.0
27	Develop, review, or expand cost code scheme	9		100.0
3	Hold separate turnover meeting between project manager and field supervisor	10	Implement an RFI tracking and processing system	100.0
7	Field supervisor reviews plans, specifications, and schedule	10		80.0
9	Conduct site visit	10		60.0
10	Compare estimated (bid) work activities & materials to planned performance	10		60.0
11	Identify value engineering and prefabrication opportunities and how to simplify the work	10		80.0
31	Develop field instructions, including panel, pull, or conduit schedules	10		60.0
2	Hold turnover meeting between estimator and project manager	11	Implement a change order tracking and processing system	80.0
3	Hold separate turnover meeting between project manager and field supervisor	11		100.0
7	Field supervisor reviews plans, specifications, and schedule,	11		100.0
9	Conduct site visit	11		80.0
10	Compare estimated (bid) work activities & materials to planned performance	11		60.0
27	Develop, review, or expand cost code scheme	11		80.0
30	Develop installation sequence and layout drawings	11		100.0
31	Develop field instructions, including panel, pull, or conduit schedules	11		60.0
3	Hold separate turnover meeting between project manager and field supervisor	12	Keep a record of all schedules and updates including delays	100.0
7	Field supervisor reviews plans, specifications, and schedule	12		80.0
9	Conduct site visit	12		80.0
11	Identify value engineering and prefabrication opportunities and how to simplify the work	12		60.0

Table C.1.1: Results of the First-Round Survey (Continued).

PCP #	PCP Task	PE#	PE Task	% of Selection by Experts)
11	Identify value engineering and prefab opportunities and how to simplify the work	17	Review bid docs to verify required materials and identify potential vendors & any vendor responsibilities	60.0
30	Develop installation sequence and layout drawings	17		80.0
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	17		60.0
2	Hold turnover meeting between estimator and project manager	19	Establish delivery dates for materials and equipment	80.0
3	Hold separate turnover meeting between project manager and field supervisor	19		80.0
9	Conduct site visit	19		100.0
27	Develop, review, or expand cost code scheme	19		60.0
3	Hold separate turnover meeting between project manager and field supervisor	22	Implement an effective material handling system on site	57.1
3	Hold separate turnover meeting between project manager and field supervisor	23	Communicate all material information to field personnel	71.4
11	Compare estimated (bid) work activities & materials to planned performance	27	Reconcile the invoice with the estimated material costs	85.7
27	Develop, review, or expand cost code scheme	28	Review contract drawing, specifications, and the bid to identify and purchase special tools	100.0
3	Hold separate turnover meeting between project manager and field supervisor	29	Schedule regular delivery and pickup of tools	71.4
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	31	Review the scope and document the subcontractors' scope of work	71.4
11	Identify value engineering and prefabrication opportunities and how to simplify the work	32	Implement subcontracts	85.7
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	33	Determine the subcontractors' schedule based on input from the subcontractors	57.1
12	Prepare construction takeoff	34	Request submittals and shop drawings from the subcontractors	71.4
3	Hold separate turnover meeting between project manager and field supervisor	35	Provide Information to the site supervisor and foreman about the subcontractors and the point of contact	85.7
2	Hold turnover meeting between estimator and project manager	40	Identify and purchase additional safety equipment as needed	85.7
27	Develop, review, or expand cost code scheme	40		100.0
3	Hold separate turnover meeting between project manager and field supervisor	42	Perform job walks regularly to ensure that the safety procedures are being followed	71.4

Table C.1.1: Results of the First-Round Survey (Continued).

PCP #	PCP Task	PE#	PE Task	% of Selection by Experts)
3	Hold separate turnover meeting between project manager and field supervisor	43	Keep the CEO/VP informed of progress and involved with the project through reports, meetings, etc	100.0
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	45	Implement procedures to communicate frequently with vendors and subcontractors	85.7
3	Hold separate turnover meeting between project manager and field supervisor	46	Implement procedures to communicate frequently with the General Contractor and Owner	85.7
3	Hold turnover meeting between estimator and project manager	54	Track change orders separately from the original scope	57.1
10	Compare estimated (bid) work activities & materials to planned performance	54		71.4
38	Customize the computerized tracking & control system (database/schedule/etc) for the current project	57	Review the schedule regularly and identify milestone dates that must be met	85.7
3	Hold separate turnover meeting between project manager and field supervisor	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones	57.1
9	Conduct site visit	60		85.7
3	Hold separate turnover meeting between project manager and field supervisor	61	Update the schedule regularly to track progress	71.4
7	Field supervisor reviews plans, specifications, and schedule	61		57.1
3	Hold separate turnover meeting between project manager and field supervisor	63	Use cost codes (Cost breakdown) to account for activities	71.4
2	Hold turnover meeting between estimator and project manager	64	Track labor costs and compare actual costs to estimated costs	57.1
10	Compare estimated (bid) work activities & materials to planned performance	64		57.1
3	Hold separate turnover meeting between project manager and field supervisor	65	Track material and subcontractors costs and compare actual costs to estimated costs	71.4
9	Conduct site visit	65		85.7
2	Hold turnover meeting between estimator and project manager	66	Once issued change orders have been approved, include them in the billing process	71.4
10	Compare estimated (bid) work activities & materials to planned performance	66		57.1
3	Hold separate turnover meeting between project manager and field supervisor	68	Compare the actual project costs to the budget to track progress	71.4
9	Conduct site visit	72	Clarify quality requirements for field personnel	71.4

Table C.1.1: Results of the First-Round Survey (Continued).

PCP #	PCP Task	PE#	PE Task	% of Selection by Experts)
9	Conduct site visit	72	Clarify quality requirements for field personnel	71.4
9	Conduct site visit	73	Check and document the quality of installation through site visits	71.4
3	Hold separate turnover meeting between project manager and field supervisor	74	Develop and implement commissioning and testing procedures	57.1
9	Conduct site visit	74		85.7
9	Conduct site visit	77	Identify and maintain the correct crew mix and manpower level	71.4
3	Hold separate turnover meeting between project manager and field supervisor	79	Ensure that all punchlist items are completed and signed off in a timely manner	57.1
7	Field supervisor reviews plans, specifications, and schedule,	79		57.1
9	Conduct site visit	79		85.7
3	Hold separate turnover meeting between project manager and field supervisor	82	Ensure that all change orders and purchase orders are closed before job completion	71.4
3	Hold separate turnover meeting between project manager and field supervisor	84	Turn all project closeout documents over to the General Contractor	71.4

Table C.1.1: Results of the First-Round Survey (Continued).

Appendix D: The Questionnaire of the Second-Round Survey

D.1 Survey Instruction

Pre-construction planning (PCP) tasks are inherently associated with project execution (PE) tasks because planning tasks are basically used to plan and set up the systems for efficiently managing subsequent project execution tasks. Accordingly, both relevant planning and execution tasks should be implemented continuously in a project for effective project management. These task combinations of planning and execution are defined as task-to-task continuity between pre-construction planning and project execution.

The purpose of this study is to investigate task-to-task continuity that pair pre-construction planning (PCP) tasks with relevant project execution (PE) tasks for electrical contractors to achieve better performance. During the survey, the participants are asked to assess the importance of PCP task completion for effective PE task execution and the importance of completing BOTH tasks to achieve cost and schedule success. The specific question described below will be assessed on a scale of 0 to 4 (0= Unimportant, 1= Of little importance, 2= Moderately important, 3= Important, and 4= Very important).

Question: How important is it to complete the PCP task to effectively implement the subsequent PE tasks, and how important is it to complete this task combination to achieve cost and schedule success?

This opinion-based survey will take you about 15~20 minutes to complete. Please click on the start button below to start the survey.

D.2 SURVEY QUESTIONNAIRES

Segment I: Question One

Q1 Please consider the following for PCP task #2: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning (PCP) Task		PE task #	Project Execution (PE) Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
2	Hold turnover meeting between estimator and project manager	→	7	Make sure the foreman has everything he or she needs to get started with the work															
2	Hold turnover meeting between estimator and project manager	→	11	Implement a change order tracking and processing system															
2	Hold turnover meeting between estimator and project manager	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
2	Hold turnover meeting between estimator and project manager	→	19	Establish delivery dates for materials and equipment															
2	Hold turnover meeting between estimator and project manager	→	25	Lock in the pricing for materials and equipment															
2	Hold turnover meeting between estimator and project manager	→	31	Review the scope and document the subcontractors' scope of work															
2	Hold turnover meeting between estimator and project manager	→	32	Implement subcontracts															
2	Hold turnover meeting between estimator and project manager	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
2	Hold turnover meeting between estimator and project manager	→	34	Request submittals and shop drawings from the subcontractors															
2	Hold turnover meeting between estimator and project manager	→	37	Make sure the subcontractors are licensed and are qualified to do the job															
2	Hold turnover meeting between estimator and project manager	→	40	Identify and purchase additional safety equipment as needed															
2	Hold turnover meeting between estimator and project manager	→	54	Track change orders separately from the original scope															
2	Hold turnover meeting between estimator and project manager	→	63	Use cost codes (Cost breakdown) to account for activities															
2	Hold turnover meeting between estimator and project manager	→	64	Track labor costs and compare actual costs to estimated costs															
2	Hold turnover meeting between estimator and project manager	→	66	Once issued change orders have been approved, include them in the billing process															
2	Hold turnover meeting between estimator and project manager	→	68	Compare the actual project costs to the budget to track progress															

Figure D.2.1: Question 1 of Segment I.

Segment I: Question Two

Q2. Please consider the following for PCP task #7: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
7	Field supervisor reviews plans, specifications, and schedule	→	1	Setup office trailer in a timely manner and in a convenient location															
7	Field supervisor reviews plans, specifications, and schedule	→	2	Setup storage trailer and lay down area in a convenient location															
7	Field supervisor reviews plans, specifications, and schedule	→	7	Make sure the foreman has everything he or she needs to get started with the work															
7	Field supervisor reviews plans, specifications, and schedule	→	8	Develop and implement a project file system															
7	Field supervisor reviews plans, specifications, and schedule	→	9	Implement a documentation control system															
7	Field supervisor reviews plans, specifications, and schedule	→	10	Implement an RFI tracking and processing system															
7	Field supervisor reviews plans, specifications, and schedule	→	11	Implement a change order tracking and processing system															
7	Field supervisor reviews plans, specifications, and schedule	→	12	Keep a record of all schedules and updates including delays															
7	Field supervisor reviews plans, specifications, and schedule	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
7	Field supervisor reviews plans, specifications, and schedule	→	19	Establish delivery dates for materials and equipment															
7	Field supervisor reviews plans, specifications, and schedule	→	22	Implement an effective material handling system on site															
7	Field supervisor reviews plans, specifications, and schedule	→	23	Communicate all material information to field personnel															
7	Field supervisor reviews plans, specifications, and schedule	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools															
7	Field supervisor reviews plans, specifications, and schedule	→	29	Schedule regular delivery and pickup of tools															
7	Field supervisor reviews plans, specifications, and schedule	→	31	Review the scope and document the subcontractors' scope of work															
7	Field supervisor reviews plans, specifications, and schedule	→	32	Implement subcontracts															
7	Field supervisor reviews plans, specifications, and schedule	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
7	Field supervisor reviews plans, specifications, and schedule	→	34	Request submittals and shop drawings from the subcontractors															
7	Field supervisor reviews plans, specifications, and schedule	→	39	Identify safety concerns associated with specific job activities															
7	Field supervisor reviews plans, specifications, and schedule	→	40	Identify and purchase additional safety equipment as needed															
7	Field supervisor reviews plans, specifications, and schedule	→	42	Perform job walks regularly to ensure that the safety procedures are being followed															
7	Field supervisor reviews plans, specifications, and schedule	→	57	Review the schedule regularly and identify milestone dates that must be met															
7	Field supervisor reviews plans, specifications, and schedule	→	58	Identify work that impacts electrical activity															
7	Field supervisor reviews plans, specifications, and schedule	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones															
7	Field supervisor reviews plans, specifications, and schedule	→	61	Update the schedule regularly to track progress															
7	Field supervisor reviews plans, specifications, and schedule	→	72	Clarify quality requirements for field personnel															
7	Field supervisor reviews plans, specifications, and schedule	→	73	Check and document the quality of installation through site visits															
7	Field supervisor reviews plans, specifications, and schedule	→	74	Develop and implement commissioning and testing procedures															
7	Field supervisor reviews plans, specifications, and schedule	→	77	Identify and maintain the correct crew mix and manpower level															
7	Field supervisor reviews plans, specifications, and schedule	→	79	Ensure that all punchlist items are completed and signed off in a timely manner															

Figure D.2.2: Question 2 of Segment I.

Segment II: Question One.

Q1. Please consider the following for PCP task #11: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	1	Setup office trailer in a timely manner and in a convenient location															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	2	Setup storage trailer and lay down area in a convenient location															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	7	Make sure the foreman has everything he or she needs to get started with the work															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	10	Implement an RFI tracking and processing system															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	31	Review the scope and document the subcontractors' scope of work															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	32	Implement subcontracts															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	34	Request submittals and shop drawings from the subcontractors															
11	Identify value engineering and prefabrication opportunities and how to simplify the work	→	58	Identify work that impacts electrical activity															

Figure D.2.3: Question 1 of Segment II.

Segment II: Question Two

Q2. Please consider the following for PCP task #3: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
3	Hold separate turnover meeting b/w project manager and field supervisor	→	1	Setup office trailer in a timely manner and in a convenient location															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	2	Setup storage trailer and lay down area in a convenient location															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	7	Make sure the foreman has everything he or she needs to get started with the work															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	8	Develop and implement a project file system															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	9	Implement a documentation control system															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	10	Implement an RFI tracking and processing system															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	11	Implement a change order tracking and processing system															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	12	Keep a record of all schedules and updates including delays															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	19	Establish delivery dates for materials and equipment															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	22	Implement an effective material handling system on site															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	23	Communicate all material information to field personnel															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	25	Lock in the pricing for materials and equipment															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	29	Schedule regular delivery and pickup of tools															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	31	Review the scope and document the subcontractors' scope of work															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	32	Implement subcontracts															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	34	Request submittals and shop drawings from the subcontractors															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	35	Provide Information to the site supervisor and foreman about the subcontractors and the point of															

Figure D.2.4: Question 2 of Segment II.

Q2. Please consider the following for PCP task #3: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
3	Hold separate turnover meeting b/w project manager and field supervisor	→	37	Make sure the subcontractors are licensed and are qualified to do the job															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	39	Identify safety concerns associated with specific job activities															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	40	Identify and purchase additional safety equipment as needed															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	42	Perform job walks regularly to ensure that the safety procedures are being followed															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	43	Keep the CEO/VP informed of progress and involved with the project through reports, meetings, etc.															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	46	Implement procedures to communicate frequently with the General Contractor and Owner															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	57	Review the schedule regularly and identify milestone dates that must be met															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	58	Identify work that impacts electrical activity															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	61	Update the schedule regularly to track progress															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	63	Use cost codes (Cost breakdown) to account for activities															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	65	Track material and subcontractors costs and compare actual costs to estimated costs															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	68	Compare the actual project costs to the budget to track progress															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	72	Clarify quality requirements for field personnel															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	73	Check and document the quality of installation through site visits															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	74	Develop and implement commissioning and testing procedures															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	77	Identify and maintain the correct crew mix and manpower level															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	78	Ensure labor hours are turned in by workers in a timely manner															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	79	Ensure that all punchlist items are completed and signed off in a timely manner															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	82	Ensure that all change orders and purchase orders are closed before job completion															
3	Hold separate turnover meeting b/w project manager and field supervisor	→	84	Turn all project closeout documents over to the General Contractor															

Figure D.2.4: Question 2 of Segment II (Continued).

Segment III: Question One

Q1 Please consider the following for PCP task #9: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
9	Conduct site visit	→	1	Setup office trailer in a timely manner and in a convenient location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	2	Setup storage trailer and lay down area in a convenient location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	7	Make sure the foreman has everything he or she needs to get started with the work	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	8	Develop and implement a project file system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	10	Implement an RFI tracking and processing system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	11	Implement a change order tracking and processing system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	12	Keep a record of all schedules and updates including delays	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	19	Establish delivery dates for materials and equipment	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	22	Implement an effective material handling system on site	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	31	Review the scope and document the subcontractors' scope of work	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	39	Identify safety concerns associated with specific job activities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	40	Identify and purchase additional safety equipment as needed	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	58	Identify work that impacts electrical activity	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	65	Track material and subcontractors costs and compare actual costs to estimated costs	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	72	Clarify quality requirements for field personnel	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	73	Check and document the quality of installation through site visits	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	74	Develop and implement commissioning and testing procedures	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	77	Identify and maintain the correct crew mix and manpower level	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	78	Ensure labor hours are turned in by workers in a timely manner	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
9	Conduct site visit	→	79	Ensure that all punchlist items are completed and signed off in a timely manner	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure D.2.5: Question 1 of Segment III.

Segment III: Question Two

Q2. Please consider the following for PCP task #10: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
10	Compare estimated (bid) work activities & materials to planned performance	→	7	Make sure the foreman has everything he or she needs to get started with the work															
10	Compare estimated (bid) work activities & materials to planned performance	→	8	Develop and implement a project file system															
10	Compare estimated (bid) work activities & materials to planned performance	→	9	Implement a documentation control system															
10	Compare estimated (bid) work activities & materials to planned performance	→	10	Implement an RFI tracking and processing system															
10	Compare estimated (bid) work activities & materials to planned performance	→	11	Implement a change order tracking and processing system															
10	Compare estimated (bid) work activities & materials to planned performance	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
10	Compare estimated (bid) work activities & materials to planned performance	→	19	Establish delivery dates for materials and equipment															
10	Compare estimated (bid) work activities & materials to planned performance	→	22	Implement an effective material handling system on site															
10	Compare estimated (bid) work activities & materials to planned performance	→	23	Communicate all material information to field personnel															
10	Compare estimated (bid) work activities & materials to planned performance	→	25	Lock in the pricing for materials and equipment															
10	Compare estimated (bid) work activities & materials to planned performance	→	27	Reconcile the invoice with the estimated material costs															
10	Compare estimated (bid) work activities & materials to planned performance	→	29	Schedule regular delivery and pickup of tools															
10	Compare estimated (bid) work activities & materials to planned performance	→	31	Review the scope and document the subcontractors' scope of work															
10	Compare estimated (bid) work activities & materials to planned performance	→	32	Implement subcontracts															
10	Compare estimated (bid) work activities & materials to planned performance	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
10	Compare estimated (bid) work activities & materials to planned performance	→	54	Track change orders separately from the original scope															
10	Compare estimated (bid) work activities & materials to planned performance	→	57	Review the schedule regularly and identify milestone dates that must be met															
10	Compare estimated (bid) work activities & materials to planned performance	→	63	Use cost codes (Cost breakdown) to account for activities															
10	Compare estimated (bid) work activities & materials to planned performance	→	64	Track labor costs and compare actual costs to estimated costs															
10	Compare estimated (bid) work activities & materials to planned performance	→	66	Once issued change orders have been approved, include them in the billing process															
10	Compare estimated (bid) work activities & materials to planned performance	→	68	Compare the actual project costs to the budget to track progress															
10	Compare estimated (bid) work activities & materials to planned performance	→	77	Identify and maintain the correct crew mix and manpower level															

Figure D.2.6: Question 2 of Segment III.

Segment IV: Question One

Q1 Please consider the following for PCP task #12: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
12	Prepare construction takeoff	→	7	Make sure the foreman has everything he or she needs to get started with the work															
12	Prepare construction takeoff	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
12	Prepare construction takeoff	→	23	Communicate all material information to field personnel															
12	Prepare construction takeoff	→	25	Lock in the pricing for materials and equipment															
12	Prepare construction takeoff	→	27	Reconcile the invoice with the estimated material costs															
12	Prepare construction takeoff	→	31	Review the scope and document the subcontractors' scope of work															
12	Prepare construction takeoff	→	32	Implement subcontracts															
12	Prepare construction takeoff	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
12	Prepare construction takeoff	→	34	Request submittals and shop drawings from the subcontractors															
12	Prepare construction takeoff	→	63	Use cost codes (Cost breakdown) to account for activities															
12	Prepare construction takeoff	→	64	Track labor costs and compare actual costs to estimated costs															
12	Prepare construction takeoff	→	65	Track material and subcontractors costs and compare actual costs to estimated costs															
12	Prepare construction takeoff	→	66	Once issued change orders have been approved, include them in the billing process															
12	Prepare construction takeoff	→	68	Compare the actual project costs to the budget to track progress															

Figure D.2.7: Question 1 of Segment IV.

Segment IV: Question Two.

Q2. Please consider the following for PCP task #27: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	e-Construction Planning Ta		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
27	Develop, review, or expand cost code scheme	→	8	Develop and implement a project file system															
27	Develop, review, or expand cost code scheme	→	9	Implement a documentation control system															
27	Develop, review, or expand cost code scheme	→	11	Implement a change order tracking and processing system															
27	Develop, review, or expand cost code scheme	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
27	Develop, review, or expand cost code scheme	→	25	Lock in the pricing for materials and equipment															
27	Develop, review, or expand cost code scheme	→	27	Reconcile the invoice with the estimated material costs															
27	Develop, review, or expand cost code scheme	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools															
27	Develop, review, or expand cost code scheme	→	31	Review the scope and document the subcontractors' scope of work															
27	Develop, review, or expand cost code scheme	→	32	Implement subcontracts															
27	Develop, review, or expand cost code scheme	→	40	Identify and purchase additional safety equipment as needed															
27	Develop, review, or expand cost code scheme	→	63	Use cost codes (Cost breakdown) to account for activities															
27	Develop, review, or expand cost code scheme	→	64	Track labor costs and compare actual costs to estimated costs															
27	Develop, review, or expand cost code scheme	→	65	Track material and subcontractors costs and compare actual costs to estimated costs															
27	Develop, review, or expand cost code scheme	→	66	Once issued change orders have been approved, include them in the billing process															
27	Develop, review, or expand cost code scheme	→	68	Compare the actual project costs to the budget to track progress															

Figure D.2.8: Question 2 of Segment IV.

Segment IV: Question Three.

Q3. Please consider the following for PCP task #30: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	e-Construction Planning Ta		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
30	Develop installation sequence and layout drawings	→	7	Make sure the foreman has everything he or she needs to get started with the work															
30	Develop installation sequence and layout drawings	→	8	Develop and implement a project file system															
30	Develop installation sequence and layout drawings	→	11	Implement a change order tracking and processing system															
30	Develop installation sequence and layout drawings	→	12	Keep a record of all schedules and updates including delays															
30	Develop installation sequence and layout drawings	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities															
30	Develop installation sequence and layout drawings	→	19	Establish delivery dates for materials and equipment															
30	Develop installation sequence and layout drawings	→	22	Implement an effective material handling system on site															
30	Develop installation sequence and layout drawings	→	23	Communicate all material information to field personnel															
30	Develop installation sequence and layout drawings	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools															
30	Develop installation sequence and layout drawings	→	29	Schedule regular delivery and pickup of tools															
30	Develop installation sequence and layout drawings	→	31	Review the scope and document the subcontractors' scope of work															
30	Develop installation sequence and layout drawings	→	32	Implement subcontracts															
30	Develop installation sequence and layout drawings	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
30	Develop installation sequence and layout drawings	→	40	Identify and purchase additional safety equipment as needed															
30	Develop installation sequence and layout drawings	→	57	Review the schedule regularly and identify milestone dates that must be met															
30	Develop installation sequence and layout drawings	→	58	Identify work that impacts electrical activity															
30	Develop installation sequence and layout drawings	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones															
30	Develop installation sequence and layout drawings	→	61	Update the schedule regularly to track progress															
30	Develop installation sequence and layout drawings	→	77	Identify and maintain the correct crew mix and manpower level															

Figure D.2.9: Question 3 of Segment IV.

Segment V: Question One.

Q1 Please consider the following for PCP task #31 (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
31	Develop field instructions, including panel, pull, or conduit schedules	→	2	Setup storage trailer and lay down area in a convenient location															
31	Develop field instructions, including panel, pull, or conduit schedules	→	7	Make sure the foreman has everything he or she needs to get started with the work															
31	Develop field instructions, including panel, pull, or conduit schedules	→	10	Implement an RFI tracking and processing system															
31	Develop field instructions, including panel, pull, or conduit schedules	→	11	Implement a change order tracking and processing system															
31	Develop field instructions, including panel, pull, or conduit schedules	→	19	Establish delivery dates for materials and equipment															
31	Develop field instructions, including panel, pull, or conduit schedules	→	22	Implement an effective material handling system on site															
31	Develop field instructions, including panel, pull, or conduit schedules	→	23	Communicate all material information to field personnel															
31	Develop field instructions, including panel, pull, or conduit schedules	→	28	Review contract drawing, specifications, and the bid to identify and purchase special tools															
31	Develop field instructions, including panel, pull, or conduit schedules	→	29	Schedule regular delivery and pickup of tools															
31	Develop field instructions, including panel, pull, or conduit schedules	→	31	Review the scope and document the subcontractors' scope of work															
31	Develop field instructions, including panel, pull, or conduit schedules	→	32	Implement subcontracts															
31	Develop field instructions, including panel, pull, or conduit schedules	→	33	Determine the subcontractors' schedule based on input from the subcontractors															
31	Develop field instructions, including panel, pull, or conduit schedules	→	39	Identify safety concerns associated with specific job activities															
31	Develop field instructions, including panel, pull, or conduit schedules	→	40	Identify and purchase additional safety equipment as needed															
31	Develop field instructions, including panel, pull, or conduit schedules	→	42	Perform job walks regularly to ensure that the safety procedures are being followed															
31	Develop field instructions, including panel, pull, or conduit schedules	→	57	Review the schedule regularly and identify milestone dates that must be met															
31	Develop field instructions, including panel, pull, or conduit schedules	→	58	Identify work that impacts electrical activity															
31	Develop field instructions, including panel, pull, or conduit schedules	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones															
31	Develop field instructions, including panel, pull, or conduit schedules	→	61	Update the schedule regularly to track progress															
31	Develop field instructions, including panel, pull, or conduit schedules	→	72	Clarify quality requirements for field personnel															
31	Develop field instructions, including panel, pull, or conduit schedules	→	73	Check and document the quality of installation through site visits															
31	Develop field instructions, including panel, pull, or conduit schedules	→	77	Identify and maintain the correct crew mix and manpower level															

Figure D.2.10: Question 1 of Segment V.

Segment V: Question Two.

Q2. Please consider the following for PCP task #38: (a) How important is it to complete the PCP task to effectively implement the subsequent PE task? (b) How important is it to complete this task combination to achieve cost and schedule success? Please assess the importance on a scale of 0 to 4. (Unimportant=0, Of little importance=1, Moderately important=2, Important=3, and Very important=4.) **If you assess (a) as "unimportant," you do not need to answer (b).**

PCP task #	Pre-Construction Planning Task		PE task #	Project Execution Task	Importance of PCP task completion for PE task Execution					Importance of completing Both tasks to achieve cost success					Importance of completing Both tasks to achieve schedule success				
					0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
38	Customize the computerized tracking & control system for the current project	→	8	Develop and implement a project file system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	9	Implement a documentation control system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	10	Implement an RFI tracking and processing system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	11	Implement a change order tracking and processing system	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	12	Keep a record of all schedules and updates including delays	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	17	Review bid docs to verify required mat'l and identify potential vendors & any vendor responsibilities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	19	Establish delivery dates for materials and equipment	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	22	Implement an effective material handling system on site	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	23	Communicate all material information to field personnel	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	27	Reconcile the invoice with the estimated material costs	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	29	Schedule regular delivery and pickup of tools	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	31	Review the scope and document the subcontractors' scope of work	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	33	Determine the subcontractors' schedule based on input from the subcontractors	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	34	Request submittals and shop drawings from the subcontractors	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	43	Keep the CEO/VP informed of progress and involved with the project through reports, meetings, etc.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	45	Implement procedures to communicate frequently with vendors and subcontractors	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	54	Track change orders separately from the original scope	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	57	Review the schedule regularly and identify milestone dates that must be met	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	60	Review the schedule routinely with field personnel to ensure all parties understand the milestones	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	61	Update the schedule regularly to track progress	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	64	Track labor costs and compare actual costs to estimated costs	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	65	Track material and subcontractors costs and compare actual costs to estimated costs	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	66	Once issued change orders have been approved, include them in the billing process	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	68	Compare the actual project costs to the budget to track progress	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	77	Identify and maintain the correct crew mix and manpower level	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	78	Ensure labor hours are turned in by workers in a timely manner	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	79	Ensure that all punchlist items are completed and signed off in a timely manner	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	82	Ensure that all change orders and purchase orders are closed before job completion	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
38	Customize the computerized tracking & control system for the current project	→	84	Turn all project closeout documents over to the General Contractor	○	○	○	○	○	○	○	○	○	○	○	○	○	○	☐

Figure D.2.11: Question 2 of Segment V.

Appendix E: Continuous Task Strings between PCP and PE

E.1 Diagrams of Continuous Task String

As a result of validation, 239 continuous task strings were identified. These validated task strings were summarized based on the 13 task string groups. Figure E.1-13 graphically describe the continuous task strings.

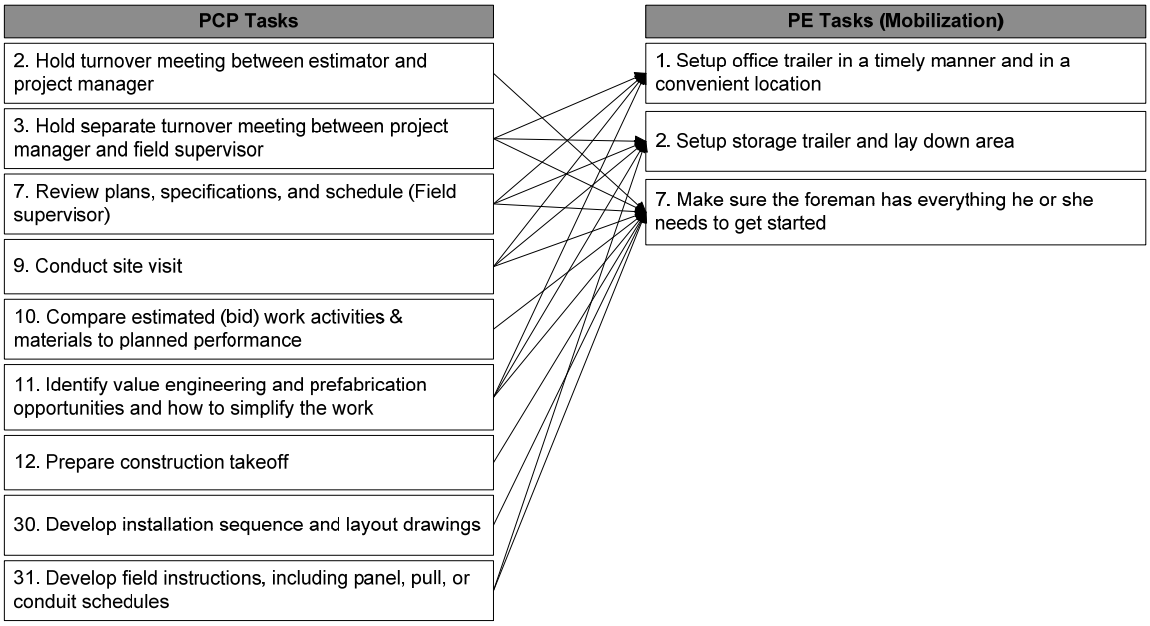

Figure E.1.1: Task String Models for Mobilization.

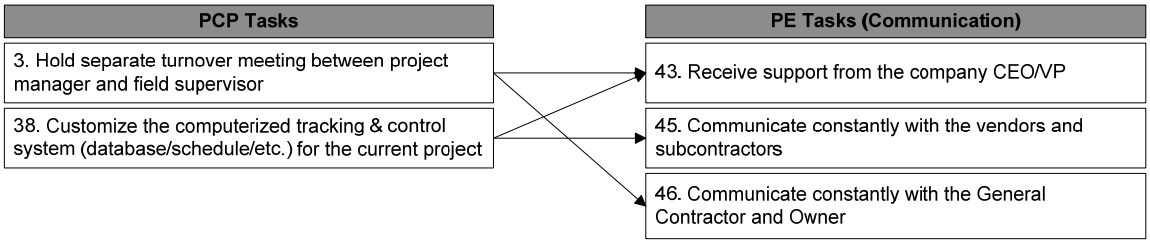

Figure E.1.2: Task String Models for Communication.

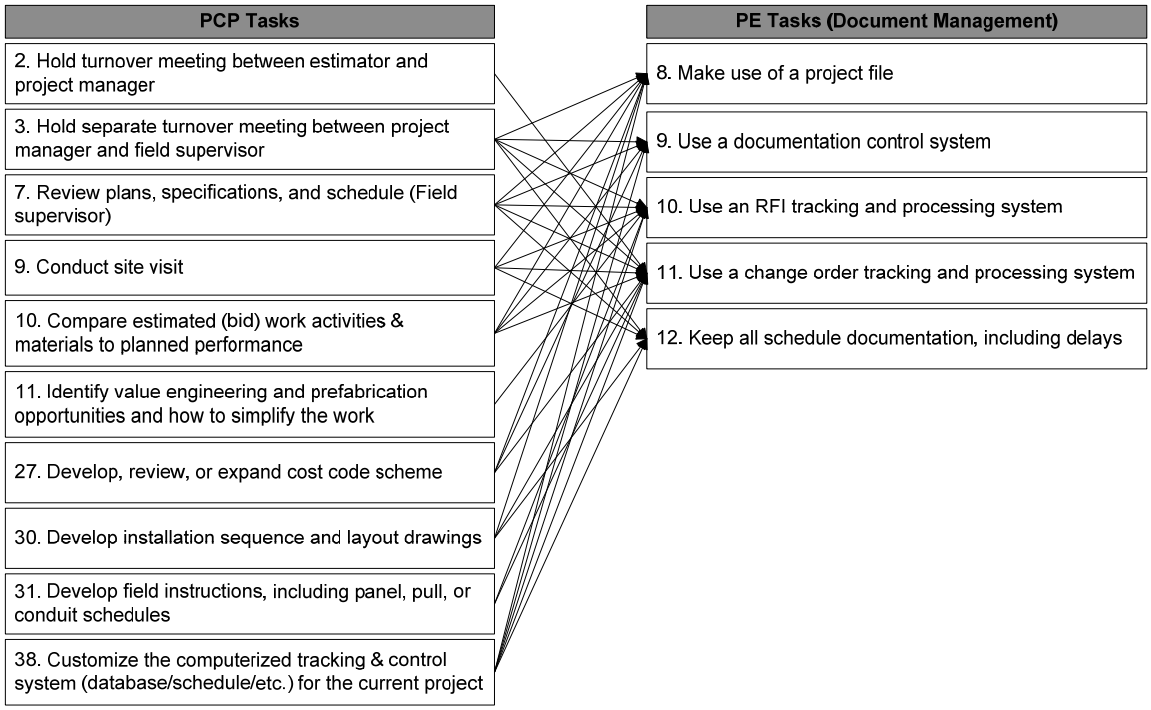

Figure E.1.3: Task String Models for Document Management.

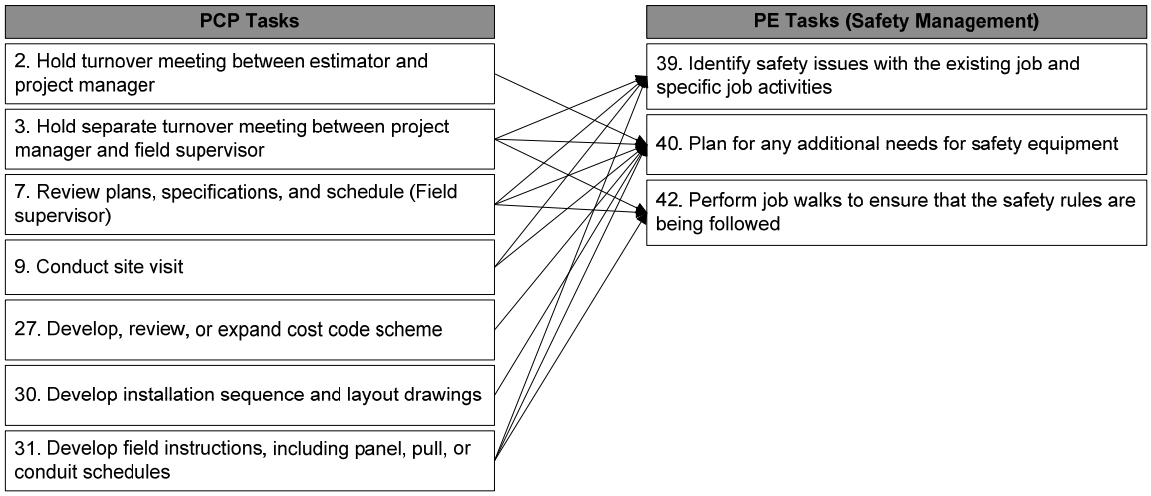

Figure E.1.4: Task String Models for Safety Management.

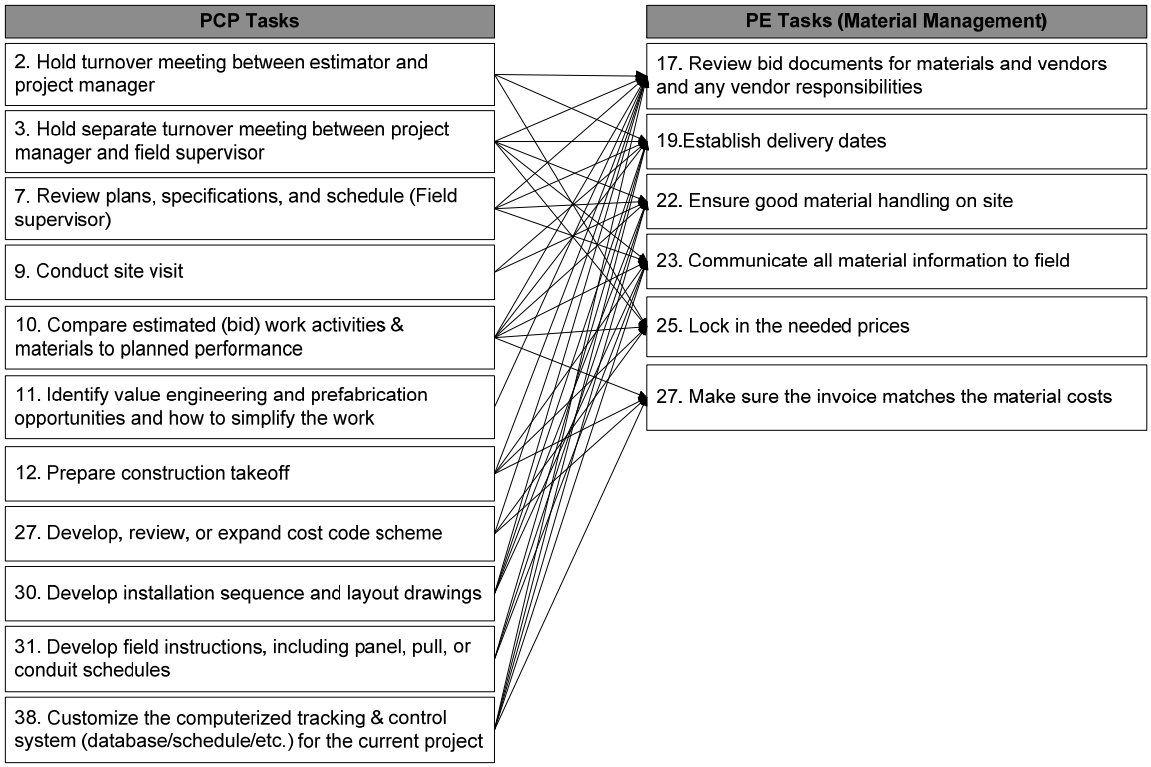

Figure E.1.5: Task String Models for Material Management.

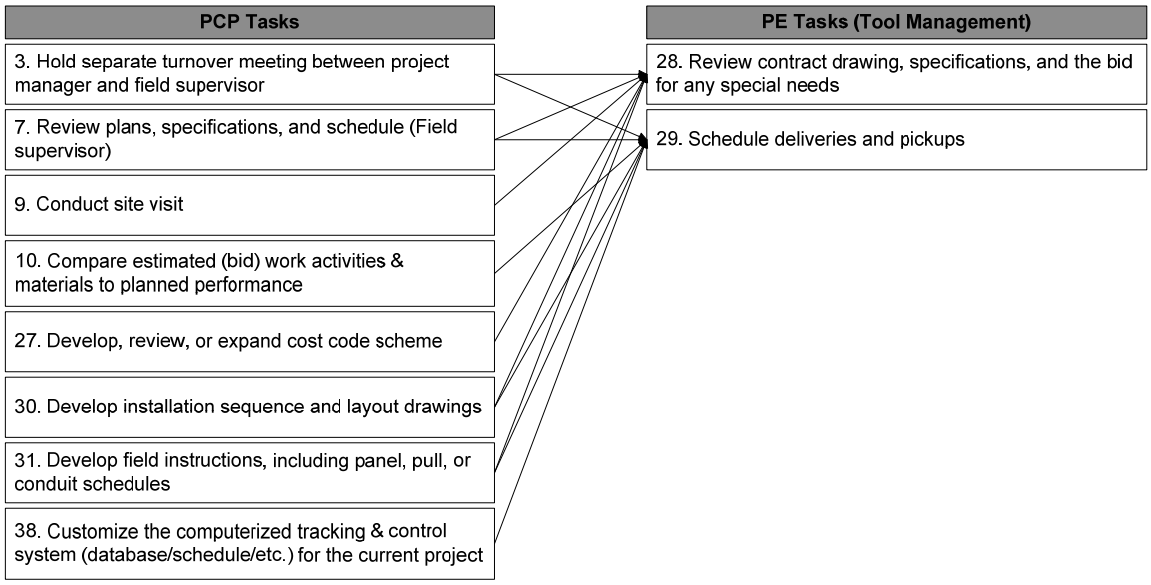

Figure E.1.6: Task String Models for Tool Management.

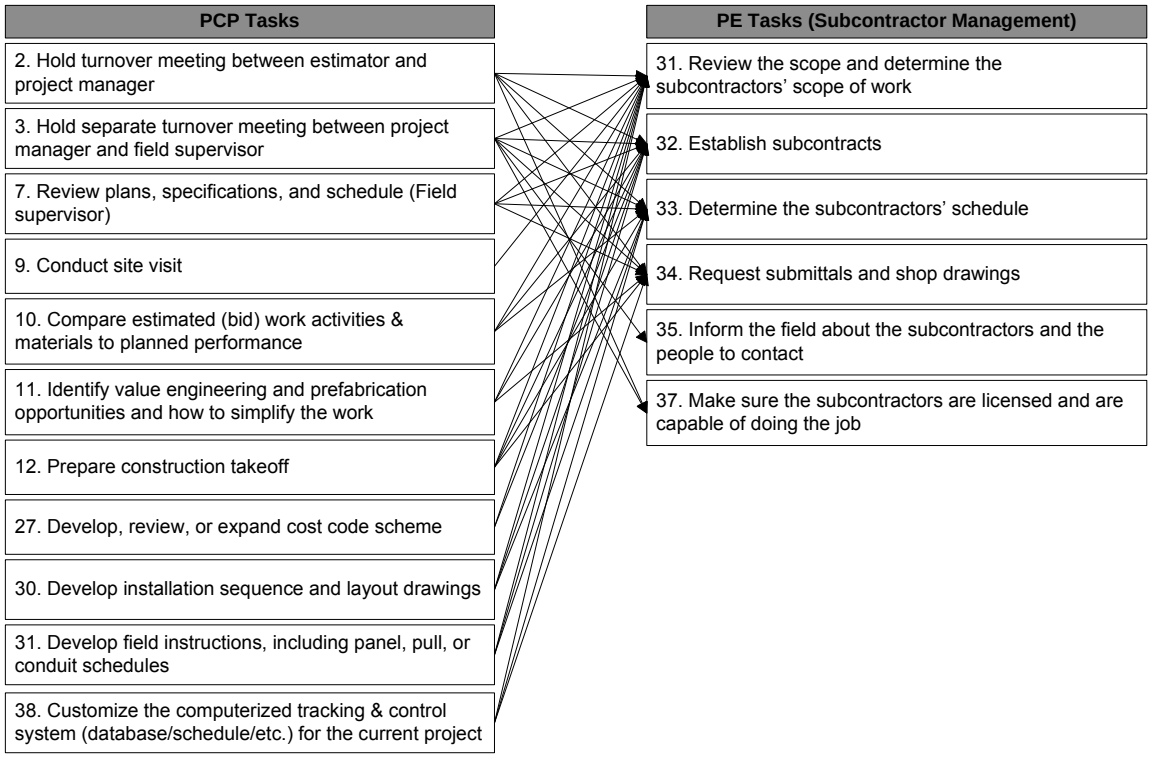

Figure E.1.7: Task String Models for Subcontractor Management.

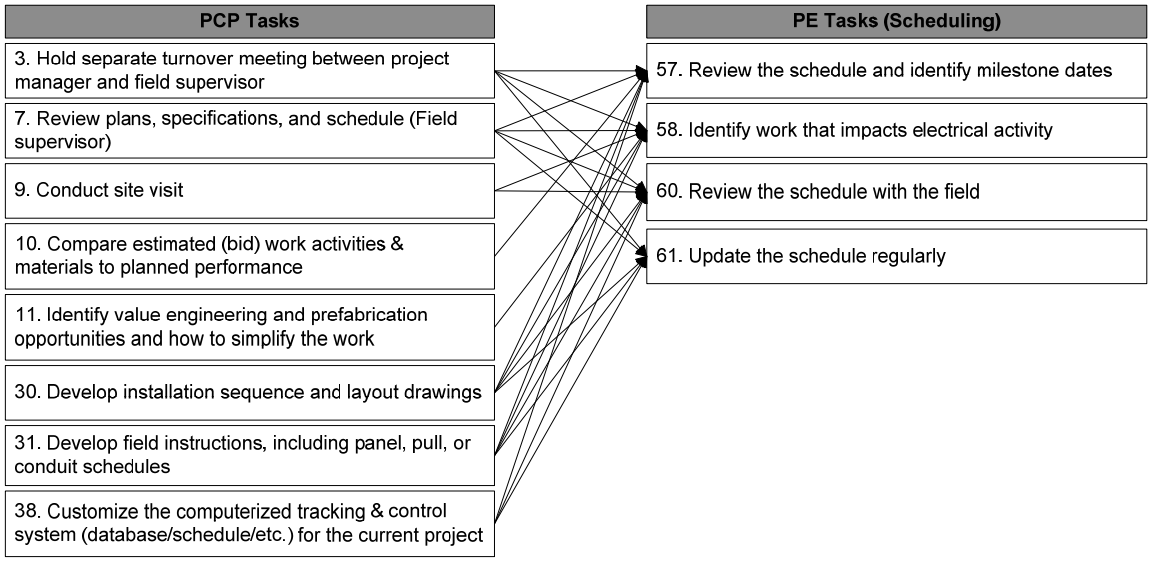

Figure E.1.8: Task String Models for Scheduling.

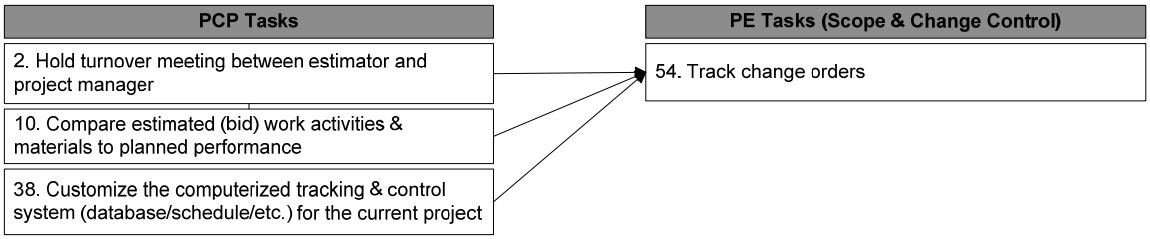

Figure E.1.9: Task String Models for Scope and Change Control.

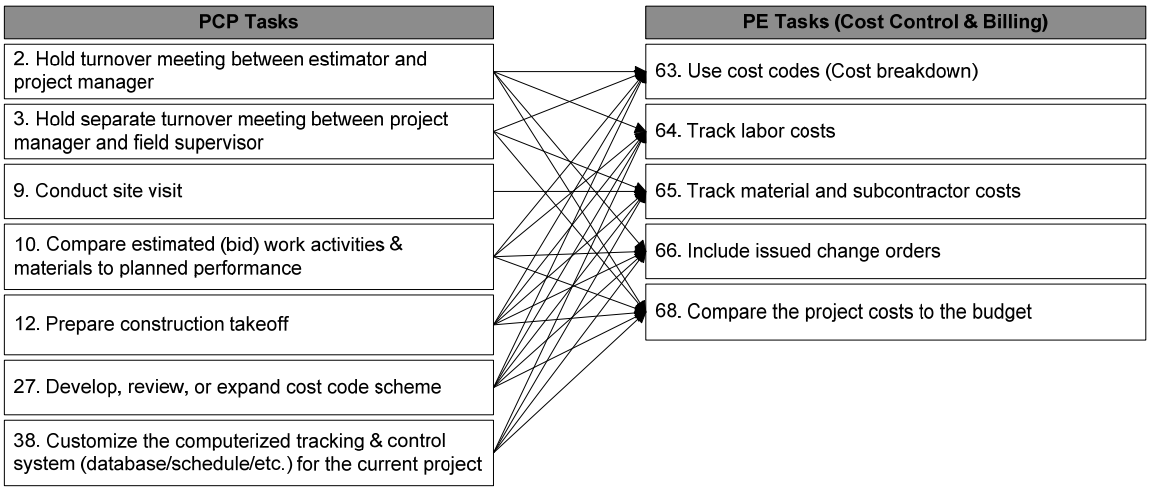

Figure E.1.10: Task String Models for Cost Control and Billing.

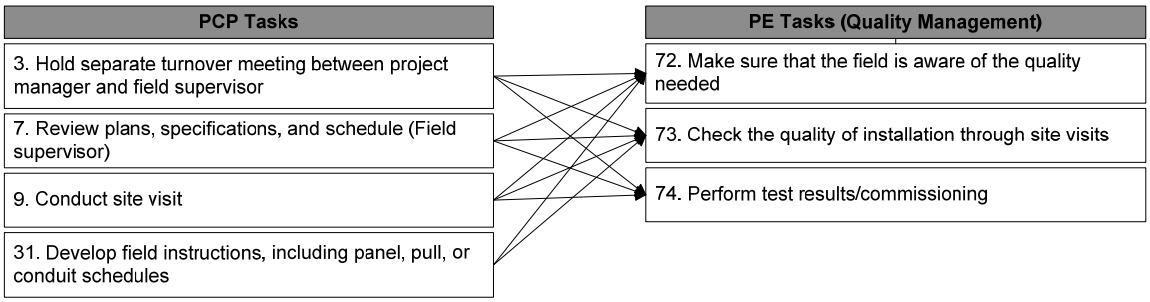

Figure E.1.11: Task String Models for Quality Management.

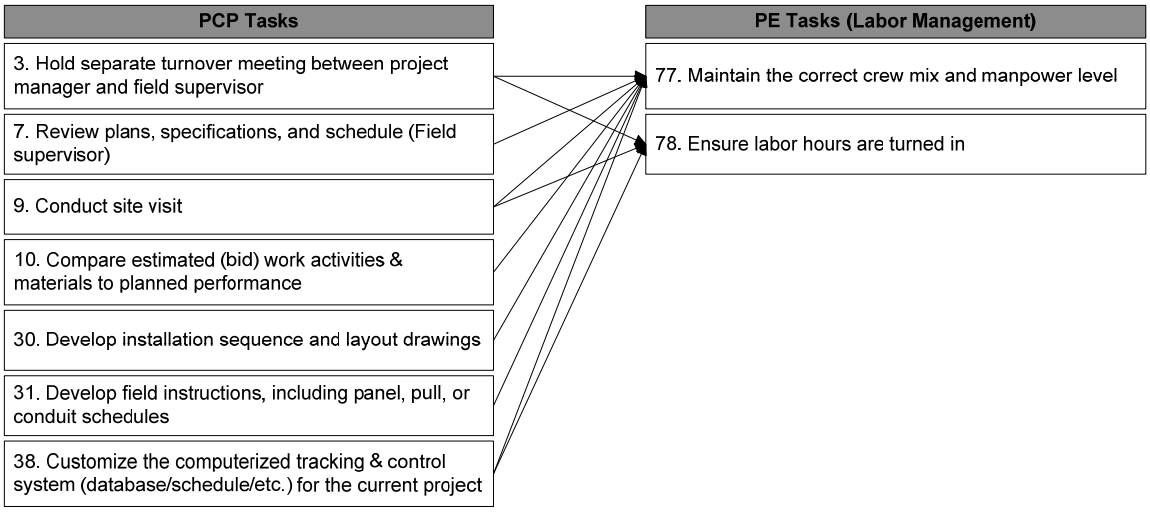

Figure E.1.12: Task String Models for Labor Management.

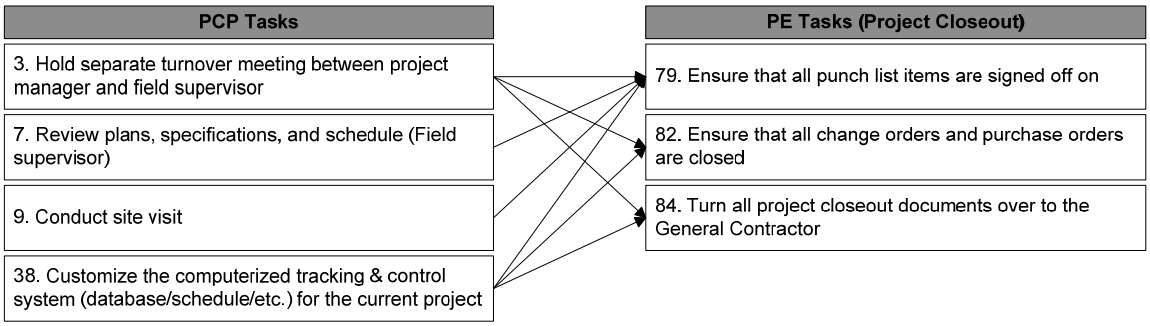

Figure E.1.13: Task String Models for Project Closeout.

E.2 LIST OF CONTINUOUS TASK STRINGS

TS#	PCP#	PCP Tasks	PE#	PE Tasks
1	3	Hold separate turnover meeting between project manager and field supervisor	1	Setup office trailer in a timely manner and in a convenient location
2	7	Review plans, specifications, and schedule (Field supervisor)	1	Setup office trailer in a timely manner and in a convenient location
3	9	Conduct site visit	1	Setup office trailer in a timely manner and in a convenient location
4	11	Identify value engineering and prefabrication opportunities and how to simplify the work	1	Setup office trailer in a timely manner and in a convenient location
5	3	Hold separate turnover meeting between project manager and field supervisor	2	Setup storage trailer and lay down area
6	7	Review plans, specifications, and schedule (Field supervisor)	2	Setup storage trailer and lay down area
7	9	Conduct site visit	2	Setup storage trailer and lay down area
8	11	Identify value engineering and prefabrication opportunities and how to simplify the work	2	Setup storage trailer and lay down area
9	31	Develop field instructions, including panel, pull, or conduit schedules	2	Setup storage trailer and lay down area
10	2	Hold turnover meeting between estimator and project manager	7	Make sure the foreman has everything he or she needs to get started
11	3	Hold separate turnover meeting between project manager and field supervisor	7	Make sure the foreman has everything he or she needs to get started
12	7	Review plans, specifications, and schedule (Field supervisor)	7	Make sure the foreman has everything he or she needs to get started
13	9	Conduct site visit	7	Make sure the foreman has everything he or she needs to get started
14	10	Compare estimated (bid) work activities & materials to planned performance	7	Make sure the foreman has everything he or she needs to get started
15	11	Identify value engineering and prefabrication opportunities and how to simplify the work	7	Make sure the foreman has everything he or she needs to get started
16	12	Prepare construction takeoff	7	Make sure the foreman has everything he or she needs to get started
17	30	Develop installation sequence and layout drawings	7	Make sure the foreman has everything he or she needs to get started
18	31	Develop field instructions, including panel, pull, or conduit schedules	7	Make sure the foreman has everything he or she needs to get started

Table E.1.1: Summary of Continuous Task Strings (1-18).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
19	3	Hold separate turnover meeting between project manager and field supervisor	8	Make use of a project file
20	7	Review plans, specifications, and schedule (Field supervisor)	8	Make use of a project file
21	9	Conduct site visit	8	Make use of a project file
22	10	Compare estimated (bid) work activities & materials to planned performance	8	Make use of a project file
23	27	Develop, review, or expand cost code scheme	8	Make use of a project file
24	30	Develop installation sequence and layout drawings	8	Make use of a project file
25	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	8	Make use of a project file
26	3	Hold separate turnover meeting between project manager and field supervisor	9	Use a documentation control system
27	7	Review plans, specifications, and schedule (Field supervisor)	9	Use a documentation control system
28	10	Compare estimated (bid) work activities & materials to planned performance	9	Use a documentation control system
29	27	Develop, review, or expand cost code scheme	9	Use a documentation control system
30	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	9	Use a documentation control system
31	3	Hold separate turnover meeting between project manager and field supervisor	10	Use an RFI tracking and processing system
32	7	Review plans, specifications, and schedule (Field supervisor)	10	Use an RFI tracking and processing system
33	9	Conduct site visit	10	Use an RFI tracking and processing system
34	10	Compare estimated (bid) work activities & materials to planned performance	10	Use an RFI tracking and processing system
35	11	Identify value engineering and prefabrication opportunities and how to simplify the work	10	Use an RFI tracking and processing system
36	31	Develop field instructions, including panel, pull, or conduit schedules	10	Use an RFI tracking and processing system
37	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	10	Use an RFI tracking and processing system

Table E.1.2: Summary of Continuous Task Strings (19-37).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
38	2	Hold turnover meeting between estimator and project manager	11	Use a change order tracking and processing system
39	3	Hold separate turnover meeting between project manager and field supervisor	11	Use a change order tracking and processing system
40	7	Review plans, specifications, and schedule (Field supervisor)	11	Use a change order tracking and processing system
41	9	Conduct site visit	11	Use a change order tracking and processing system
42	10	Compare estimated (bid) work activities & materials to planned performance	11	Use a change order tracking and processing system
43	27	Develop, review, or expand cost code scheme	11	Use a change order tracking and processing system
44	30	Develop installation sequence and layout drawings	11	Use a change order tracking and processing system
45	31	Develop field instructions, including panel, pull, or conduit schedules	11	Use a change order tracking and processing system
46	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	11	Use a change order tracking and processing system
47	3	Hold separate turnover meeting between project manager and field supervisor	12	Keep all schedule documentation, including delays
48	7	Review plans, specifications, and schedule (Field supervisor)	12	Keep all schedule documentation, including delays
49	9	Conduct site visit	12	Keep all schedule documentation, including delays
50	30	Develop installation sequence and layout drawings	12	Keep all schedule documentation, including delays
51	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	12	Keep all schedule documentation, including delays
52	2	Hold turnover meeting between estimator and project manager	17	Review bid documents for materials and vendors and any vendor responsibilities
53	3	Hold separate turnover meeting between project manager and field supervisor	17	Review bid documents for materials and vendors and any vendor responsibilities
54	7	Review plans, specifications, and schedule (Field supervisor)	17	Review bid documents for materials and vendors and any vendor responsibilities
55	10	Compare estimated (bid) work activities & materials to planned performance	17	Review bid documents for materials and vendors and any vendor responsibilities
56	11	Identify value engineering and prefabrication opportunities and how to simplify the work	17	Review bid documents for materials and vendors and any vendor responsibilities
57	12	Prepare construction takeoff	17	Review bid documents for materials and vendors and any vendor responsibilities

Table E.1.3: Summary of Continuous Task Strings (38-57).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
58	27	Develop, review, or expand cost code scheme	17	Review bid documents for materials and vendors and any vendor responsibilities
59	30	Develop installation sequence and layout drawings	17	Review bid documents for materials and vendors and any vendor responsibilities
60	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	17	Review bid documents for materials and vendors and any vendor responsibilities
61	2	Hold turnover meeting between estimator and project manager	19	Establish delivery dates
62	3	Hold separate turnover meeting between project manager and field supervisor	19	Establish delivery dates
63	7	Review plans, specifications, and schedule (Field supervisor)	19	Establish delivery dates
64	9	Conduct site visit	19	Establish delivery dates
65	10	Compare estimated (bid) work activities & materials to planned performance	19	Establish delivery dates
66	30	Develop installation sequence and layout drawings	19	Establish delivery dates
67	31	Develop field instructions, including panel, pull, or conduit schedules	19	Establish delivery dates
68	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	19	Establish delivery dates
69	3	Hold separate turnover meeting between project manager and field supervisor	22	Ensure good material handling on site
70	7	Review plans, specifications, and schedule (Field supervisor)	22	Ensure good material handling on site
71	9	Conduct site visit	22	Ensure good material handling on site
72	10	Compare estimated (bid) work activities & materials to planned performance	22	Ensure good material handling on site
73	30	Develop installation sequence and layout drawings	22	Ensure good material handling on site
74	31	Develop field instructions, including panel, pull, or conduit schedules	22	Ensure good material handling on site
75	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	22	Ensure good material handling on site

Table E.1.4: Summary of Continuous Task Strings (58-75).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
76	3	Hold separate turnover meeting between project manager and field supervisor	23	Communicate all material information to field
77	7	Review plans, specifications, and schedule (Field supervisor)	23	Communicate all material information to field
78	10	Compare estimated (bid) work activities & materials to planned performance	23	Communicate all material information to field
79	12	Prepare construction takeoff	23	Communicate all material information to field
80	30	Develop installation sequence and layout drawings	23	Communicate all material information to field
81	31	Develop field instructions, including panel, pull, or conduit schedules	23	Communicate all material information to field
82	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	23	Communicate all material information to field
83	2	Hold turnover meeting between estimator and project manager	25	Lock in the needed prices
84	3	Hold separate turnover meeting between project manager and field supervisor	25	Lock in the needed prices
85	10	Compare estimated (bid) work activities & materials to planned performance	25	Lock in the needed prices
86	12	Prepare construction takeoff	25	Lock in the needed prices
87	27	Develop, review, or expand cost code scheme	25	Lock in the needed prices
88	10	Compare estimated (bid) work activities & materials to planned performance	27	Make sure the invoice matches the material costs
89	12	Prepare construction takeoff	27	Make sure the invoice matches the material costs
90	27	Develop, review, or expand cost code scheme	27	Make sure the invoice matches the material costs
91	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	27	Make sure the invoice matches the material costs
92	3	Hold separate turnover meeting between project manager and field supervisor	28	Review contract drawing, specifications, and the bid for any special needs
93	7	Review plans, specifications, and schedule (Field supervisor)	28	Review contract drawing, specifications, and the bid for any special needs
94	9	Conduct site visit	28	Review contract drawing, specifications, and the bid for any special needs
95	27	Develop, review, or expand cost code scheme	28	Review contract drawing, specifications, and the bid for any special needs

Table E.1.5: Summary of Continuous Task Strings (76-95).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
96	30	Develop installation sequence and layout drawings	28	Review contract drawing, specifications, and the bid for any special needs
97	31	Develop field instructions, including panel, pull, or conduit schedules	28	Review contract drawing, specifications, and the bid for any special needs
98	3	Hold separate turnover meeting between project manager and field supervisor	29	Schedule deliveries and pickups
99	7	Review plans, specifications, and schedule (Field supervisor)	29	Schedule deliveries and pickups
100	10	Compare estimated (bid) work activities & materials to planned performance	29	Schedule deliveries and pickups
101	30	Develop installation sequence and layout drawings	29	Schedule deliveries and pickups
102	31	Develop field instructions, including panel, pull, or conduit schedules	29	Schedule deliveries and pickups
103	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	29	Schedule deliveries and pickups
104	2	Hold turnover meeting between estimator and project manager	31	Review the scope and determine the subcontractors' scope of work
105	3	Hold separate turnover meeting between project manager and field supervisor	31	Review the scope and determine the subcontractors' scope of work
106	7	Review plans, specifications, and schedule (Field supervisor)	31	Review the scope and determine the subcontractors' scope of work
107	9	Conduct site visit	31	Review the scope and determine the subcontractors' scope of work
108	10	Compare estimated (bid) work activities & materials to planned performance	31	Review the scope and determine the subcontractors' scope of work
109	11	Identify value engineering and prefabrication opportunities and how to simplify the work	31	Review the scope and determine the subcontractors' scope of work
110	12	Prepare construction takeoff	31	Review the scope and determine the subcontractors' scope of work
111	27	Develop, review, or expand cost code scheme	31	Review the scope and determine the subcontractors' scope of work
112	30	Develop installation sequence and layout drawings	31	Review the scope and determine the subcontractors' scope of work
113	31	Develop field instructions, including panel, pull, or conduit schedules	31	Review the scope and determine the subcontractors' scope of work
114	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	31	Review the scope and determine the subcontractors' scope of work

Table E.1.6: Summary of Continuous Task Strings (96-114).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
115	2	Hold turnover meeting between estimator and project manager	32	Establish subcontracts
116	3	Hold separate turnover meeting between project manager and field supervisor	32	Establish subcontracts
117	7	Review plans, specifications, and schedule (Field supervisor)	32	Establish subcontracts
118	10	Compare estimated (bid) work activities & materials to planned performance	32	Establish subcontracts
119	11	Identify value engineering and prefabrication opportunities and how to simplify the work	32	Establish subcontracts
120	12	Prepare construction takeoff	32	Establish subcontracts
121	27	Develop, review, or expand cost code scheme	32	Establish subcontracts
122	30	Develop installation sequence and layout drawings	32	Establish subcontracts
123	31	Develop field instructions, including panel, pull, or conduit schedules	32	Establish subcontracts
124	2	Hold turnover meeting between estimator and project manager	33	Determine the subcontractors' schedule
125	3	Hold separate turnover meeting between project manager and field supervisor	33	Determine the subcontractors' schedule
126	7	Review plans, specifications, and schedule (Field supervisor)	33	Determine the subcontractors' schedule
127	10	Compare estimated (bid) work activities & materials to planned performance	33	Determine the subcontractors' schedule
128	12	Prepare construction takeoff	33	Determine the subcontractors' schedule
129	30	Develop installation sequence and layout drawings	33	Determine the subcontractors' schedule
130	31	Develop field instructions, including panel, pull, or conduit schedules	33	Determine the subcontractors' schedule
131	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	33	Determine the subcontractors' schedule
132	2	Hold turnover meeting between estimator and project manager	34	Request submittals and shop drawings
133	3	Hold separate turnover meeting between project manager and field supervisor	34	Request submittals and shop drawings
134	7	Review plans, specifications, and schedule (Field supervisor)	34	Request submittals and shop drawings
135	11	Identify value engineering and prefabrication opportunities and how to simplify the work	34	Request submittals and shop drawings
136	12	Prepare construction takeoff	34	Request submittals and shop drawings
137	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	34	Request submittals and shop drawings

Table E.1.7: Summary of Continuous Task Strings (115-137).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
138	3	Hold separate turnover meeting between project manager and field supervisor	35	Inform the field about the subcontractors and the people to contact
139	2	Hold turnover meeting between estimator and project manager	37	Make sure the subcontractors are licensed and are capable of doing the job
140	3	Hold separate turnover meeting between project manager and field supervisor	37	Make sure the subcontractors are licensed and are capable of doing the job
141	3	Hold separate turnover meeting between project manager and field supervisor	39	Identify safety issues with the existing job and specific job activities
142	7	Review plans, specifications, and schedule (Field supervisor)	39	Identify safety issues with the existing job and specific job activities
143	9	Conduct site visit	39	Identify safety issues with the existing job and specific job activities
144	31	Develop field instructions, including panel, pull, or conduit schedules	39	Identify safety issues with the existing job and specific job activities
145	2	Hold turnover meeting between estimator and project manager	40	Plan for any additional needs for safety equipment
146	3	Hold separate turnover meeting between project manager and field supervisor	40	Plan for any additional needs for safety equipment
147	7	Review plans, specifications, and schedule (Field supervisor)	40	Plan for any additional needs for safety equipment
148	9	Conduct site visit	40	Plan for any additional needs for safety equipment
149	27	Develop, review, or expand cost code scheme	40	Plan for any additional needs for safety equipment
150	30	Develop installation sequence and layout drawings	40	Plan for any additional needs for safety equipment
151	31	Develop field instructions, including panel, pull, or conduit schedules	40	Plan for any additional needs for safety equipment
152	3	Hold separate turnover meeting between project manager and field supervisor	42	Perform job walks to ensure that the safety rules are being followed
153	7	Review plans, specifications, and schedule (Field supervisor)	42	Perform job walks to ensure that the safety rules are being followed
154	31	Develop field instructions, including panel, pull, or conduit schedules	42	Perform job walks to ensure that the safety rules are being followed
155	3	Hold separate turnover meeting between project manager and field supervisor	43	Receive support from the company CEO/VP
156	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	43	Receive support from the company CEO/VP

Table E.1.8: Summary of Continuous Task Strings (138-156).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
157	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	45	Communicate constantly with the vendors and subcontractors
158	3	Hold separate turnover meeting between project manager and field supervisor	46	Communicate constantly with the General Contractor and Owner
159	2	Hold turnover meeting between estimator and project manager	54	Track change orders
160	10	Compare estimated (bid) work activities & materials to planned performance	54	Track change orders
161	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	54	Track change orders
162	3	Hold separate turnover meeting between project manager and field supervisor	57	Review the schedule and identify milestone dates
163	7	Review plans, specifications, and schedule (Field supervisor)	57	Review the schedule and identify milestone dates
164	10	Compare estimated (bid) work activities & materials to planned performance	57	Review the schedule and identify milestone dates
165	30	Develop installation sequence and layout drawings	57	Review the schedule and identify milestone dates
166	31	Develop field instructions, including panel, pull, or conduit schedules	57	Review the schedule and identify milestone dates
167	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	57	Review the schedule and identify milestone dates
168	3	Hold separate turnover meeting between project manager and field supervisor	58	Identify work that impacts electrical activity
169	7	Review plans, specifications, and schedule (Field supervisor)	58	Identify work that impacts electrical activity
170	9	Conduct site visit	58	Identify work that impacts electrical activity
171	11	Identify value engineering and prefabrication opportunities and how to simplify the work	58	Identify work that impacts electrical activity
172	30	Develop installation sequence and layout drawings	58	Identify work that impacts electrical activity
173	31	Develop field instructions, including panel, pull, or conduit schedules	58	Identify work that impacts electrical activity

Table E.1.9: Summary of Continuous Task Strings (157-173).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
174	3	Hold separate turnover meeting between project manager and field supervisor	60	Review the schedule with the field
175	7	Review plans, specifications, and schedule (Field supervisor)	60	Review the schedule with the field
176	9	Conduct site visit	60	Review the schedule with the field
177	30	Develop installation sequence and layout drawings	60	Review the schedule with the field
178	31	Develop field instructions, including panel, pull, or conduit schedules	60	Review the schedule with the field
179	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	60	Review the schedule with the field
180	3	Hold separate turnover meeting between project manager and field supervisor	61	Update the schedule regularly
181	7	Review plans, specifications, and schedule (Field supervisor)	61	Update the schedule regularly
182	30	Develop installation sequence and layout drawings	61	Update the schedule regularly
183	31	Develop field instructions, including panel, pull, or conduit schedules	61	Update the schedule regularly
184	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	61	Update the schedule regularly
185	2	Hold turnover meeting between estimator and project manager	63	Use cost codes (Cost breakdown)
186	3	Hold separate turnover meeting between project manager and field supervisor	63	Use cost codes (Cost breakdown)
187	10	Compare estimated (bid) work activities & materials to planned performance	63	Use cost codes (Cost breakdown)
188	12	Prepare construction takeoff	63	Use cost codes (Cost breakdown)
189	27	Develop, review, or expand cost code scheme	63	Use cost codes (Cost breakdown)
190	2	Hold turnover meeting between estimator and project manager	64	Track labor costs
191	10	Compare estimated (bid) work activities & materials to planned performance	64	Track labor costs
192	12	Prepare construction takeoff	64	Track labor costs
193	27	Develop, review, or expand cost code scheme	64	Track labor costs
194	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	64	Track labor costs

Table E.1.10: Summary of Continuous Task Strings (174-194).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
195	3	Hold separate turnover meeting between project manager and field supervisor	65	Track material and subcontractor costs
196	9	Conduct site visit	65	Track material and subcontractor costs
197	12	Prepare construction takeoff	65	Track material and subcontractor costs
198	27	Develop, review, or expand cost code scheme	65	Track material and subcontractor costs
199	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	65	Track material and subcontractor costs
200	2	Hold turnover meeting between estimator and project manager	66	Include issued change orders
201	10	Compare estimated (bid) work activities & materials to planned performance	66	Include issued change orders
202	12	Prepare construction takeoff	66	Include issued change orders
203	27	Develop, review, or expand cost code scheme	66	Include issued change orders
204	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	66	Include issued change orders
205	2	Hold turnover meeting between estimator and project manager	68	Compare the project costs to the budget
206	3	Hold separate turnover meeting between project manager and field supervisor	68	Compare the project costs to the budget
207	10	Compare estimated (bid) work activities & materials to planned performance	68	Compare the project costs to the budget
208	12	Prepare construction takeoff	68	Compare the project costs to the budget
209	27	Develop, review, or expand cost code scheme	68	Compare the project costs to the budget
210	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	68	Compare the project costs to the budget
211	3	Hold separate turnover meeting between project manager and field supervisor	72	Make sure that the field is aware of the quality needed
212	7	Review plans, specifications, and schedule (Field supervisor)	72	Make sure that the field is aware of the quality needed
213	9	Conduct site visit	72	Make sure that the field is aware of the quality needed
214	31	Develop field instructions, including panel, pull, or conduit schedules	72	Make sure that the field is aware of the quality needed
215	3	Hold separate turnover meeting between project manager and field supervisor	73	Check the quality of installation through site visits
216	7	Review plans, specifications, and schedule (Field supervisor)	73	Check the quality of installation through site visits
217	9	Conduct site visit	73	Check the quality of installation through site visits
218	31	Develop field instructions, including panel, pull, or conduit schedules	73	Check the quality of installation through site visits

Table E.1.11: Summary of Continuous Task Strings (195-218).

TS#	PCP#	PCP Tasks	PE#	PE Tasks
219	3	Hold separate turnover meeting between project manager and field supervisor	74	Perform test results/commissioning
220	7	Review plans, specifications, and schedule (Field supervisor)	74	Perform test results/commissioning
221	9	Conduct site visit	74	Perform test results/commissioning
222	3	Hold separate turnover meeting between project manager and field supervisor	77	Maintain the correct crew mix and manpower level
223	7	Review plans, specifications, and schedule (Field supervisor)	77	Maintain the correct crew mix and manpower level
224	9	Conduct site visit	77	Maintain the correct crew mix and manpower level
225	10	Compare estimated (bid) work activities & materials to planned performance	77	Maintain the correct crew mix and manpower level
226	30	Develop installation sequence and layout drawings	77	Maintain the correct crew mix and manpower level
227	31	Develop field instructions, including panel, pull, or conduit schedules	77	Maintain the correct crew mix and manpower level
228	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	77	Maintain the correct crew mix and manpower level
229	3	Hold separate turnover meeting between project manager and field supervisor	78	Ensure labor hours are turned in
230	9	Conduct site visit	78	Ensure labor hours are turned in
231	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	78	Ensure labor hours are turned in
232	3	Hold separate turnover meeting between project manager and field supervisor	79	Ensure that all punch list items are signed off on
233	7	Review plans, specifications, and schedule (Field supervisor)	79	Ensure that all punch list items are signed off on
234	9	Conduct site visit	79	Ensure that all punch list items are signed off on
235	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	79	Ensure that all punch list items are signed off on
236	3	Hold separate turnover meeting between project manager and field supervisor	82	Ensure that all change orders and purchase orders are closed
237	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	82	Ensure that all change orders and purchase orders are closed
238	3	Hold separate turnover meeting between project manager and field supervisor	84	Turn all project closeout documents over to the General Contractor
239	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	84	Turn all project closeout documents over to the General Contractor

Table E.1.12: Summary of Continuous Task Strings (219-239).

Appendix F: Validated Basic Task Strings

F.1 VALIDATED BASIC TASK STRINGS FOR COST SUCCESS

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	4	11	Identify value engineering and prefabrication opportunities and how to simplify the work	1	Setup office trailer in a timely manner and in a convenient location
Basic	6	7	Review plans, specifications, and schedule (Field supervisor)	2	Setup storage trailer and lay down area
Basic	7	9	Conduct site visit	2	Setup storage trailer and lay down area
Basic	10	2	Hold turnover meeting between estimator and project manager	7	Make sure the foreman has everything he or she needs to get started
Basic	11	3	Hold separate turnover meeting between project manager and field supervisor	7	Make sure the foreman has everything he or she needs to get started
Basic	15	11	Identify value engineering and prefabrication opportunities and how to simplify the work	7	Make sure the foreman has everything he or she needs to get started
Basic	16	12	Prepare construction takeoff	7	Make sure the foreman has everything he or she needs to get started
Basic	17	30	Develop installation sequence and layout drawings	7	Make sure the foreman has everything he or she needs to get started
Basic	18	31	Develop field instructions, including panel, pull, or conduit schedules	7	Make sure the foreman has everything he or she needs to get started
Basic	19	3	Hold separate turnover meeting between project manager and field supervisor	8	Make use of a project file
Basic	20	7	Review plans, specifications, and schedule (Field supervisor)	8	Make use of a project file
Basic	22	10	Compare estimated (bid) work activities & materials to planned performance	8	Make use of a project file
Basic	23	27	Develop, review, or expand cost code scheme	8	Make use of a project file
Basic	25	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	8	Make use of a project file
Basic	26	3	Hold separate turnover meeting between project manager and field supervisor	9	Use a documentation control system
Basic	27	7	Review plans, specifications, and schedule (Field supervisor)	9	Use a documentation control system
Basic	29	27	Develop, review, or expand cost code scheme	9	Use a documentation control system
Basic	32	7	Review plans, specifications, and schedule (Field supervisor)	10	Use an RFI tracking and processing system
Basic	33	9	Conduct site visit	10	Use an RFI tracking and processing system
Basic	35	11	Identify value engineering and prefabrication opportunities and how to simplify the work	10	Use an RFI tracking and processing system
Basic	37	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	10	Use an RFI tracking and processing system

Table F.1.1: Summary of Validated Basic Strings for Cost.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	38	2	Hold turnover meeting between estimator and project manager	11	Use a change order tracking and processing system
Basic	42	10	Compare estimated (bid) work activities & materials to planned performance	11	Use a change order tracking and processing system
Basic	43	27	Develop, review, or expand cost code scheme	11	Use a change order tracking and processing system
Basic	45	31	Develop field instructions, including panel, pull, or conduit schedules	11	Use a change order tracking and processing system
Basic	48	7	Review plans, specifications, and schedule (Field supervisor)	12	Keep all schedule documentation, including delays
Basic	49	9	Conduct site visit	12	Keep all schedule documentation, including delays
Basic	53	3	Hold separate turnover meeting between project manager and field supervisor	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	54	7	Review plans, specifications, and schedule (Field supervisor)	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	57	12	Prepare construction takeoff	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	58	27	Develop, review, or expand cost code scheme	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	61	2	Hold turnover meeting between estimator and project manager	19	Establish delivery dates
Basic	63	7	Review plans, specifications, and schedule (Field supervisor)	19	Establish delivery dates
Basic	65	10	Compare estimated (bid) work activities & materials to planned performance	19	Establish delivery dates
Basic	66	30	Develop installation sequence and layout drawings	19	Establish delivery dates
Basic	67	31	Develop field instructions, including panel, pull, or conduit schedules	19	Establish delivery dates
Basic	68	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	19	Establish delivery dates
Basic	69	3	Hold separate turnover meeting between project manager and field supervisor	22	Ensure good material handling on site
Basic	70	7	Review plans, specifications, and schedule (Field supervisor)	22	Ensure good material handling on site
Basic	71	9	Conduct site visit	22	Ensure good material handling on site
Basic	72	10	Compare estimated (bid) work activities & materials to planned performance	22	Ensure good material handling on site
Basic	74	31	Develop field instructions, including panel, pull, or conduit schedules	22	Ensure good material handling on site

Table F.1.1: Summary of Validated Basic Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	79	12	Prepare construction takeoff	23	Communicate all material information to field
Basic	81	31	Develop field instructions, including panel, pull, or conduit schedules	23	Communicate all material information to field
Basic	82	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	23	Communicate all material information to field
Basic	83	2	Hold turnover meeting between estimator and project manager	25	Lock in the needed prices
Basic	84	3	Hold separate turnover meeting between project manager and field supervisor	25	Lock in the needed prices
Basic	85	10	Compare estimated (bid) work activities & materials to planned performance	25	Lock in the needed prices
Basic	86	12	Prepare construction takeoff	25	Lock in the needed prices
Basic	87	27	Develop, review, or expand cost code scheme	25	Lock in the needed prices
Basic	88	10	Compare estimated (bid) work activities & materials to planned performance	27	Make sure the invoice matches the material costs
Basic	89	12	Prepare construction takeoff	27	Make sure the invoice matches the material costs
Basic	90	27	Develop, review, or expand cost code scheme	27	Make sure the invoice matches the material costs
Basic	97	31	Develop field instructions, including panel, pull, or conduit schedules	28	Review contract drawing, specifications, and the bid for any special needs
Basic	98	3	Hold separate turnover meeting between project manager and field supervisor	29	Schedule deliveries and pickups
Basic	99	7	Review plans, specifications, and schedule (Field supervisor)	29	Schedule deliveries and pickups
Basic	102	31	Develop field instructions, including panel, pull, or conduit schedules	29	Schedule deliveries and pickups
Basic	105	3	Hold separate turnover meeting between project manager and field supervisor	31	Review the scope and determine the subcontractors' scope of work
Basic	109	11	Identify value engineering and prefabrication opportunities and how to simplify the work	31	Review the scope and determine the subcontractors' scope of work
Basic	110	12	Prepare construction takeoff	31	Review the scope and determine the subcontractors' scope of work
Basic	112	30	Develop installation sequence and layout drawings	31	Review the scope and determine the subcontractors' scope of work
Basic	113	31	Develop field instructions, including panel, pull, or conduit schedules	31	Review the scope and determine the subcontractors' scope of work
Basic	118	10	Compare estimated (bid) work activities & materials to planned performance	32	Establish subcontracts
Basic	119	11	Identify value engineering and prefabrication opportunities and how to simplify the work	32	Establish subcontracts

Table F.1.1: Summary of Validated Basic Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	125	3	Hold separate turnover meeting between project manager and field supervisor	33	Determine the subcontractors' schedule
Basic	126	7	Review plans, specifications, and schedule (Field supervisor)	33	Determine the subcontractors' schedule
Basic	127	10	Compare estimated (bid) work activities & materials to planned performance	33	Determine the subcontractors' schedule
Basic	128	12	Prepare construction takeoff	33	Determine the subcontractors' schedule
Basic	129	30	Develop installation sequence and layout drawings	33	Determine the subcontractors' schedule
Basic	130	31	Develop field instructions, including panel, pull, or conduit schedules	33	Determine the subcontractors' schedule
Basic	135	11	Identify value engineering and prefabrication opportunities and how to simplify the work	34	Request submittals and shop drawings
Basic	137	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	34	Request submittals and shop drawings
Basic	138	3	Hold separate turnover meeting between project manager and field supervisor	35	Inform the field about the subcontractors and the people to contact
Basic	141	3	Hold separate turnover meeting between project manager and field supervisor	39	Identify safety issues with the existing job and specific job activities
Basic	142	7	Review plans, specifications, and schedule (Field supervisor)	39	Identify safety issues with the existing job and specific job activities
Basic	144	31	Develop field instructions, including panel, pull, or conduit schedules	39	Identify safety issues with the existing job and specific job activities
Basic	146	3	Hold separate turnover meeting between project manager and field supervisor	40	Plan for any additional needs for safety equipment
Basic	147	7	Review plans, specifications, and schedule (Field supervisor)	40	Plan for any additional needs for safety equipment
Basic	149	27	Develop, review, or expand cost code scheme	40	Plan for any additional needs for safety equipment
Basic	150	30	Develop installation sequence and layout drawings	40	Plan for any additional needs for safety equipment
Basic	151	31	Develop field instructions, including panel, pull, or conduit schedules	40	Plan for any additional needs for safety equipment
Basic	152	3	Hold separate turnover meeting between project manager and field supervisor	42	Perform job walks to ensure that the safety rules are being followed
Basic	153	7	Review plans, specifications, and schedule (Field supervisor)	42	Perform job walks to ensure that the safety rules are being followed
Basic	154	31	Develop field instructions, including panel, pull, or conduit schedules	42	Perform job walks to ensure that the safety rules are being followed
Basic	157	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	45	Communicate constantly with the vendors and subcontractors
Basic	158	3	Hold separate turnover meeting between project manager and field supervisor	46	Communicate constantly with the General Contractor and Owner

Table F.1.1: Summary of Validated Basic Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	163	7	Review plans, specifications, and schedule (Field supervisor)	57	Review the schedule and identify milestone dates
Basic	165	30	Develop installation sequence and layout drawings	57	Review the schedule and identify milestone dates
Basic	168	3	Hold separate turnover meeting between project manager and field supervisor	58	Identify work that impacts electrical activity
Basic	169	7	Review plans, specifications, and schedule (Field supervisor)	58	Identify work that impacts electrical activity
Basic	172	30	Develop installation sequence and layout drawings	58	Identify work that impacts electrical activity
Basic	174	3	Hold separate turnover meeting between project manager and field supervisor	60	Review the schedule with the field
Basic	175	7	Review plans, specifications, and schedule (Field supervisor)	60	Review the schedule with the field
Basic	176	9	Conduct site visit	60	Review the schedule with the field
Basic	180	3	Hold separate turnover meeting between project manager and field supervisor	61	Update the schedule regularly
Basic	181	7	Review plans, specifications, and schedule (Field supervisor)	61	Update the schedule regularly
Basic	182	30	Develop installation sequence and layout drawings	61	Update the schedule regularly
Basic	186	3	Hold separate turnover meeting between project manager and field supervisor	63	Use cost codes (Cost breakdown)
Basic	187	10	Compare estimated (bid) work activities & materials to planned performance	63	Use cost codes (Cost breakdown)
Basic	189	27	Develop, review, or expand cost code scheme	63	Use cost codes (Cost breakdown)
Basic	190	2	Hold turnover meeting between estimator and project manager	64	Track labor costs
Basic	195	3	Hold separate turnover meeting between project manager and field supervisor	65	Track material and subcontractor costs
Basic	198	27	Develop, review, or expand cost code scheme	65	Track material and subcontractor costs
Basic	200	2	Hold turnover meeting between estimator and project manager	66	Include issued change orders
Basic	201	10	Compare estimated (bid) work activities & materials to planned performance	66	Include issued change orders
Basic	202	12	Prepare construction takeoff	66	Include issued change orders
Basic	203	27	Develop, review, or expand cost code scheme	66	Include issued change orders

Table F.1.1: Summary of Validated Basic Strings for Cost (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	213	9	Conduct site visit	72	Make sure that the field is aware of the quality needed
Basic	215	3	Hold separate turnover meeting between project manager and field supervisor	73	Check the quality of installation through site visits
Basic	216	7	Review plans, specifications, and schedule (Field supervisor)	73	Check the quality of installation through site visits
Basic	222	3	Hold separate turnover meeting between project manager and field supervisor	77	Maintain the correct crew mix and manpower level
Basic	223	7	Review plans, specifications, and schedule (Field supervisor)	77	Maintain the correct crew mix and manpower level
Basic	226	30	Develop installation sequence and layout drawings	77	Maintain the correct crew mix and manpower level
Basic	229	3	Hold separate turnover meeting between project manager and field supervisor	78	Ensure labor hours are turned in
Basic	235	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	79	Ensure that all punch list items are signed off on
Basic	237	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	82	Ensure that all change orders and purchase orders are closed
Basic	239	38	Customize the computerized tracking & control system (database/schedule/etc.) for the current project	84	Turn all project closeout documents over to the General Contractor

Table F.1.1: Summary of Validated Basic Strings for Cost (Continued).

F.2 VALIDATED BASIC TASK STRINGS FOR SCHEDULE SUCCESS

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	1	3	Hold separate turnover meeting between project manager and field supervisor	1	Setup office trailer in a timely manner and in a convenient location
Basic	2	7	Review plans, specifications, and schedule (Field supervisor)	1	Setup office trailer in a timely manner and in a convenient location
Basic	3	9	Conduct site visit	1	Setup office trailer in a timely manner and in a convenient location
Basic	4	11	Identify value engineering and prefabrication opportunities and how to simplify the work	1	Setup office trailer in a timely manner and in a convenient location
Basic	5	3	Hold separate turnover meeting between project manager and field supervisor	2	Setup storage trailer and lay down area
Basic	6	7	Review plans, specifications, and schedule (Field supervisor)	2	Setup storage trailer and lay down area
Basic	7	9	Conduct site visit	2	Setup storage trailer and lay down area
Basic	8	11	Identify value engineering and prefabrication opportunities and how to simplify the work	2	Setup storage trailer and lay down area
Basic	9	31	Develop field instructions, including panel, pull, or conduit schedules	2	Setup storage trailer and lay down area
Basic	10	2	Hold turnover meeting between estimator and project manager	7	Make sure the foreman has everything he or she needs to get started
Basic	14	10	Compare estimated (bid) work activities & materials to planned performance	7	Make sure the foreman has everything he or she needs to get started
Basic	17	30	Develop installation sequence and layout drawings	7	Make sure the foreman has everything he or she needs to get started
Basic	18	31	Develop field instructions, including panel, pull, or conduit schedules	7	Make sure the foreman has everything he or she needs to get started
Basic	19	3	Hold separate turnover meeting between project manager and field supervisor	8	Make use of a project file
Basic	20	7	Review plans, specifications, and schedule (Field supervisor)	8	Make use of a project file
Basic	21	9	Conduct site visit	8	Make use of a project file
Basic	22	10	Compare estimated (bid) work activities & materials to planned performance	8	Make use of a project file
Basic	27	7	Review plans, specifications, and schedule (Field supervisor)	9	Use a documentation control system
Basic	34	10	Compare estimated (bid) work activities & materials to planned performance	10	Use an RFI tracking and processing system
Basic	36	31	Develop field instructions, including panel, pull, or conduit schedules	10	Use an RFI tracking and processing system

Table F.2.1: Summary of Validated Basic Strings for Schedule.

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	38	2	Hold turnover meeting between estimator and project manager	11	Use a change order tracking and processing system
Basic	39	3	Hold separate turnover meeting between project manager and field supervisor	11	Use a change order tracking and processing system
Basic	40	7	Review plans, specifications, and schedule (Field supervisor)	11	Use a change order tracking and processing system
Basic	41	9	Conduct site visit	11	Use a change order tracking and processing system
Basic	42	10	Compare estimated (bid) work activities & materials to planned performance	11	Use a change order tracking and processing system
Basic	43	27	Develop, review, or expand cost code scheme	11	Use a change order tracking and processing system
Basic	44	30	Develop installation sequence and layout drawings	11	Use a change order tracking and processing system
Basic	45	31	Develop field instructions, including panel, pull, or conduit schedules	11	Use a change order tracking and processing system
Basic	48	7	Review plans, specifications, and schedule (Field supervisor)	12	Keep all schedule documentation, including delays
Basic	50	30	Develop installation sequence and layout drawings	12	Keep all schedule documentation, including delays
Basic	53	3	Hold separate turnover meeting between project manager and field supervisor	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	54	7	Review plans, specifications, and schedule (Field supervisor)	17	Review bid documents for materials and vendors and any vendor responsibilities
Basic	61	2	Hold turnover meeting between estimator and project manager	19	Establish delivery dates
Basic	62	3	Hold separate turnover meeting between project manager and field supervisor	19	Establish delivery dates
Basic	63	7	Review plans, specifications, and schedule (Field supervisor)	19	Establish delivery dates
Basic	65	10	Compare estimated (bid) work activities & materials to planned performance	19	Establish delivery dates
Basic	66	30	Develop installation sequence and layout drawings	19	Establish delivery dates
Basic	67	31	Develop field instructions, including panel, pull, or conduit schedules	19	Establish delivery dates
Basic	69	3	Hold separate turnover meeting between project manager and field supervisor	22	Ensure good material handling on site
Basic	70	7	Review plans, specifications, and schedule (Field supervisor)	22	Ensure good material handling on site
Basic	71	9	Conduct site visit	22	Ensure good material handling on site
Basic	72	10	Compare estimated (bid) work activities & materials to planned performance	22	Ensure good material handling on site
Basic	73	30	Develop installation sequence and layout drawings	22	Ensure good material handling on site

Table F.2.2: Summary of Validated Basic Strings for Schedule (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	76	3	Hold separate turnover meeting between project manager and field supervisor	23	Communicate all material information to field
Basic	77	7	Review plans, specifications, and schedule (Field supervisor)	23	Communicate all material information to field
Basic	78	10	Compare estimated (bid) work activities & materials to planned performance	23	Communicate all material information to field
Basic	80	30	Develop installation sequence and layout drawings	23	Communicate all material information to field
Basic	81	31	Develop field instructions, including panel, pull, or conduit schedules	23	Communicate all material information to field
Basic	84	3	Hold separate turnover meeting between project manager and field supervisor	25	Lock in the needed prices
Basic	85	10	Compare estimated (bid) work activities & materials to planned performance	25	Lock in the needed prices
Basic	86	12	Prepare construction takeoff	25	Lock in the needed prices
Basic	87	27	Develop, review, or expand cost code scheme	25	Lock in the needed prices
Basic	89	12	Prepare construction takeoff	27	Make sure the invoice matches the material costs
Basic	90	27	Develop, review, or expand cost code scheme	27	Make sure the invoice matches the material costs
Basic	92	3	Hold separate turnover meeting between project manager and field supervisor	28	Review contract drawing, specifications, and the bid for any special needs
Basic	93	7	Review plans, specifications, and schedule (Field supervisor)	28	Review contract drawing, specifications, and the bid for any special needs
Basic	96	30	Develop installation sequence and layout drawings	28	Review contract drawing, specifications, and the bid for any special needs
Basic	97	31	Develop field instructions, including panel, pull, or conduit schedules	28	Review contract drawing, specifications, and the bid for any special needs
Basic	98	3	Hold separate turnover meeting between project manager and field supervisor	29	Schedule deliveries and pickups
Basic	99	7	Review plans, specifications, and schedule (Field supervisor)	29	Schedule deliveries and pickups
Basic	101	30	Develop installation sequence and layout drawings	29	Schedule deliveries and pickups
Basic	102	31	Develop field instructions, including panel, pull, or conduit schedules	29	Schedule deliveries and pickups
Basic	105	3	Hold separate turnover meeting between project manager and field supervisor	31	Review the scope and determine the subcontractors' scope of work
Basic	108	10	Compare estimated (bid) work activities & materials to planned performance	31	Review the scope and determine the subcontractors' scope of work
Basic	109	11	Identify value engineering and prefabrication opportunities and how to simplify the work	31	Review the scope and determine the subcontractors' scope of work

Table F.2.2: Summary of Validated Basic Strings for Schedule (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	110	12	Prepare construction takeoff	31	Review the scope and determine the subcontractors' scope of work
Basic	111	27	Develop, review, or expand cost code scheme	31	Review the scope and determine the subcontractors' scope of work
Basic	112	30	Develop installation sequence and layout drawings	31	Review the scope and determine the subcontractors' scope of work
Basic	113	31	Develop field instructions, including panel, pull, or conduit schedules	31	Review the scope and determine the subcontractors' scope of work
Basic	115	2	Hold turnover meeting between estimator and project manager	32	Establish subcontracts
Basic	116	3	Hold separate turnover meeting between project manager and field supervisor	32	Establish subcontracts
Basic	117	7	Review plans, specifications, and schedule (Field supervisor)	32	Establish subcontracts
Basic	118	10	Compare estimated (bid) work activities & materials to planned performance	32	Establish subcontracts
Basic	119	11	Identify value engineering and prefabrication opportunities and how to simplify the work	32	Establish subcontracts
Basic	120	12	Prepare construction takeoff	32	Establish subcontracts
Basic	122	30	Develop installation sequence and layout drawings	32	Establish subcontracts
Basic	125	3	Hold separate turnover meeting between project manager and field supervisor	33	Determine the subcontractors' schedule
Basic	127	10	Compare estimated (bid) work activities & materials to planned performance	33	Determine the subcontractors' schedule
Basic	128	12	Prepare construction takeoff	33	Determine the subcontractors' schedule
Basic	129	30	Develop installation sequence and layout drawings	33	Determine the subcontractors' schedule
Basic	130	31	Develop field instructions, including panel, pull, or conduit schedules	33	Determine the subcontractors' schedule
Basic	132	2	Hold turnover meeting between estimator and project manager	34	Request submittals and shop drawings
Basic	133	3	Hold separate turnover meeting between project manager and field supervisor	34	Request submittals and shop drawings
Basic	134	7	Review plans, specifications, and schedule (Field supervisor)	34	Request submittals and shop drawings
Basic	135	11	Identify value engineering and prefabrication opportunities and how to simplify the work	34	Request submittals and shop drawings
Basic	136	12	Prepare construction takeoff	34	Request submittals and shop drawings
Basic	138	3	Hold separate turnover meeting between project manager and field supervisor	35	Inform the field about the subcontractors and the people to contact
Basic	140	3	Hold separate turnover meeting between project manager and field supervisor	37	Make sure the subcontractors are licensed and are capable of doing the job

Table F.2.2: Summary of Validated Basic Strings for Schedule (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	141	3	Hold separate turnover meeting between project manager and field supervisor	39	Identify safety issues with the existing job and specific job activities
Basic	142	7	Review plans, specifications, and schedule (Field supervisor)	39	Identify safety issues with the existing job and specific job activities
Basic	143	9	Conduct site visit	39	Identify safety issues with the existing job and specific job activities
Basic	144	31	Develop field instructions, including panel, pull, or conduit schedules	39	Identify safety issues with the existing job and specific job activities
Basic	146	3	Hold separate turnover meeting between project manager and field supervisor	40	Plan for any additional needs for safety equipment
Basic	147	7	Review plans, specifications, and schedule (Field supervisor)	40	Plan for any additional needs for safety equipment
Basic	148	9	Conduct site visit	40	Plan for any additional needs for safety equipment
Basic	150	30	Develop installation sequence and layout drawings	40	Plan for any additional needs for safety equipment
Basic	151	31	Develop field instructions, including panel, pull, or conduit schedules	40	Plan for any additional needs for safety equipment
Basic	152	3	Hold separate turnover meeting between project manager and field supervisor	42	Perform job walks to ensure that the safety rules are being followed
Basic	153	7	Review plans, specifications, and schedule (Field supervisor)	42	Perform job walks to ensure that the safety rules are being followed
Basic	154	31	Develop field instructions, including panel, pull, or conduit schedules	42	Perform job walks to ensure that the safety rules are being followed
Basic	155	3	Hold separate turnover meeting between project manager and field supervisor	43	Receive support from the company CEO/VP
Basic	160	10	Compare estimated (bid) work activities & materials to planned performance	54	Track change orders
Basic	163	7	Review plans, specifications, and schedule (Field supervisor)	57	Review the schedule and identify milestone dates
Basic	165	30	Develop installation sequence and layout drawings	57	Review the schedule and identify milestone dates
Basic	169	7	Review plans, specifications, and schedule (Field supervisor)	58	Identify work that impacts electrical activity
Basic	172	30	Develop installation sequence and layout drawings	58	Identify work that impacts electrical activity
Basic	174	3	Hold separate turnover meeting between project manager and field supervisor	60	Review the schedule with the field
Basic	175	7	Review plans, specifications, and schedule (Field supervisor)	60	Review the schedule with the field
Basic	176	9	Conduct site visit	60	Review the schedule with the field
Basic	177	30	Develop installation sequence and layout drawings	60	Review the schedule with the field

Table F.2.2: Summary of Validated Basic Strings for Schedule (Continued).

Ranking of TS	TS#	PCP#	PCP Tasks	PE#	PE Tasks
Basic	181	7	Review plans, specifications, and schedule (Field supervisor)	61	Update the schedule regularly
Basic	182	30	Develop installation sequence and layout drawings	61	Update the schedule regularly
Basic	186	3	Hold separate turnover meeting between project manager and field supervisor	63	Use cost codes (Cost breakdown)
Basic	190	2	Hold turnover meeting between estimator and project manager	64	Track labor costs
Basic	191	10	Compare estimated (bid) work activities & materials to planned performance	64	Track labor costs
Basic	192	12	Prepare construction takeoff	64	Track labor costs
Basic	193	27	Develop, review, or expand cost code scheme	64	Track labor costs
Basic	195	3	Hold separate turnover meeting between project manager and field supervisor	65	Track material and subcontractor costs
Basic	197	12	Prepare construction takeoff	65	Track material and subcontractor costs
Basic	201	10	Compare estimated (bid) work activities & materials to planned performance	66	Include issued change orders
Basic	202	12	Prepare construction takeoff	66	Include issued change orders
Basic	211	3	Hold separate turnover meeting between project manager and field supervisor	72	Make sure that the field is aware of the quality needed
Basic	212	7	Review plans, specifications, and schedule (Field supervisor)	72	Make sure that the field is aware of the quality needed
Basic	213	9	Conduct site visit	72	Make sure that the field is aware of the quality needed
Basic	214	31	Develop field instructions, including panel, pull, or conduit schedules	72	Make sure that the field is aware of the quality needed
Basic	219	3	Hold separate turnover meeting between project manager and field supervisor	74	Perform test results/commissioning
Basic	220	7	Review plans, specifications, and schedule (Field supervisor)	74	Perform test results/commissioning
Basic	223	7	Review plans, specifications, and schedule (Field supervisor)	77	Maintain the correct crew mix and manpower level
Basic	226	30	Develop installation sequence and layout drawings	77	Maintain the correct crew mix and manpower level
Basic	232	3	Hold separate turnover meeting between project manager and field supervisor	79	Ensure that all punch list items are signed off on
Basic	233	7	Review plans, specifications, and schedule (Field supervisor)	79	Ensure that all punch list items are signed off on
Basic	236	3	Hold separate turnover meeting between project manager and field supervisor	82	Ensure that all change orders and purchase orders are closed
Basic	238	3	Hold separate turnover meeting between project manager and field supervisor	84	Turn all project closeout documents over to the General Contractor

Table F.2.2: Summary of Validated Basic Strings for Schedule (Continued).

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Vita

Dae Young Kim, the son of Soo-Seob Kim and Jong-Hee Kweon, was born in Busan, Republic of Korea on January 23, 1977, the son of Soo Seob Kim and Jong Hee Kwon. When he completed his studies at Sa-Jik High School in 1995, he engered Pusan National University in Busan, where he received the degree of Bachelor of Science in Architectural Engineering in February 2003. He also did his military service from November 1996 to January 2003. He is a distinguished recipient of the Graduate Study Abroad Scholarship by the Korea Science and Engineering Foundation (KOSEF) from 2004 to 2006. During his time as a KOSEF scholar, he completed a Master of Science degree in Civil Engineering from the University of Texas at Austin. As part of his scholarly activities, he conducted research on *Descriptive Multi-Resources and Multi-Projects Costs for a Subcontractor*. Prior to becoming a graduate student at The University of Texas at Austin, He worked as a construction engineer for Hyundai Engineering and Construction Co. Ltd. in Korea. He also worked as an engineer at the Estimating and Budgeting Department of the Building Division, headquartered in South Korea, followed by an assignment to oversee construction of a 1,800-unit residential development. During this important assignment, he was in charge of general project management, including cost management, preparation of progress payment reports, time management, construction schedule development, safety management, and the safety education of laborers.

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